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29, 1930

TRANSACTIONS

OF THE

American Fisheries Society

SIXTIETH ANNUAL MEETING

Toronto, Ontario

August 27, 28, and 29, 1930

Published Annually by the Society
Hartford, Connecticut
1930

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AMERICAN FISHERIES SOCIETY

Organized 1870 Incorporated 1910

*OFFICERS FOR 1930-1931

President	E. Lee LeCompte, Baltimore, Md.
Vice-President	James A. Rodd, Ottawa, Canada
Secretary-Treasurer	†Carlos Avery, New York, N. Y.
Librarian	John W. Titcomb, Hartford, Conn.

Vice-Presidents of Divisions

Fish Culture	M. C. James, Washington, D. C.
Aquatic Biology and Physics	W. J. K. Harkness, Toronto, Canada
Commercial Fishing	Clarence Birdseye, Gloucester, Mass.
Angling	Fred A. Westerman, Lansing, Mich.
Protection and Legislation	I. T. Quinn, Montgomery, Ala.

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W. E. Albert	Des Moines, Iowa
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Wilbert A. Clemens	Nanaimo, B. C.
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Frederic C. Walcott	Norfolk, Conn.

Committee on Relations with National and State Governments

Lewis Radcliffe, *Chairman*	Washington, D. C.
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B. O. Webster	Madison, Wis.
H. B. Ward	Urbana, Illinois
George W. McCullough	St. Paul, Minn.
John Van Oosten	Ann Arbor, Mich.

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David L. Belding	Boston, Mass.
John W. Titcomb	Hartford, Conn.
George C. Embody	Ithaca, N. Y.
H. S. Davis	Washington, D. C.

*For street addresses see membership list.
†Deceased. Succeeded by Seth Gordon, Investment Bldg., Washington, D. C.

Presidents' Terms of Service and Places of Meeting

The first meeting of the Society occurred December 20, 1870. The organization then effected continued until February, 1872, when the second meeting was held. Since that time there has been a meeting each year, as shown below. The respective presidents were elected at the meeting, at the place, and for a period shown opposite their names, but they presided at the subsequent meeting.

1.	William Clift........	1870-1872	New York, N. Y.
2.	William Clift........	1872-1873	Albany, N. Y.
3.	William Clift........	1873-1874	New York, N. Y.
4.	Robert B. Roosevelt..	1874-1875	New York, N. Y.
5.	Robert B. Roosevelt..	1875-1876	New York, N. Y.
6.	Robert B. Roosevelt..	1876-1877*	New York, N. Y.
7.	Robert B. Roosevelt..	1877-1878	New York, N. Y.
8.	Robert B. Roosevelt..	1878-1879	New York, N. Y.
9.	Robert B. Roosevelt..	1879-1880	New York, N. Y.
10.	Robert B. Roosevelt..	1880-1881	New York, N. Y.
11.	Robert B. Roosevelt..	1881-1882	New York, N. Y.
12.	George Shepard Page.	1882-1883	New York, N. Y.
13.	James Benkard......	1883-1884	New York, N. Y.
14.	Theodore Lyman.....	1884-1885	Washington, D. C.
15.	Marshall McDonald..	1885-1886	Washington, D. C.
16.	W. M. Hudson.......	1886-1887	Chicago, Ill.
17.	William L. May......	1887-1888	Washington, D. C.
18.	John Bissell.........	1888-1889	Detroit, Mich.
19.	Eugene G. Blackford..	1889-1890	Philadelphia, Pa.
20.	Eugene G. Blackford..	1890-1891	Put-in-Bay, Ohio
21.	James A. Henshall...	1891-1892	Washington, D. C.
22.	Herschel Whitaker...	1892-1893	New York, N. Y.
23.	Henry C. Ford......	1893-1894	Chicago, Ill.
24.	William L. May.....	1894-1895	Philadelphia, Pa.
25.	L. D. Huntington.....	1895-1896	New York, N. Y.
26.	Herschel Whitaker...	1896-1897	New York, N. Y.
27.	William L. May.....	1897-1898	Detroit, Mich.
28.	George F. Peabody...	1898-1899	Omaha, Nebr.
29.	John W. Titcomb....	1899-1900	Niagara Falls, N. Y.
30.	F. B. Dickerson......	1900-1901	Woods Hole, Mass.
31.	E. E. Bryant........	1901-1902	Milwaukee, Wis.
32.	George M. Bowers...	1902-1903	Put-in-Bay, Ohio
33.	Frank N. Clark......	1903-1904	Woods Hole, Mass.
34.	Henry T. Root......	1904-1905	Atlantic City, N. J.

*A special meeting was held at the Centennial Grounds, Philadelphia, Pa., October 6 and 7, 1876.

35.	C. D. Joslyn	1905-1906	White Sulphur Springs, W. Va.
36.	E. A. Birge	1906-1907	Grand Rapids, Mich.
37.	Hugh M. Smith	1907-1908	Erie, Pa.
38.	Tarleton H. Bean	1908-1909	Washington, D. C.
39.	Seymour Bower	1909-1910	Toledo, Ohio
40.	William E. Meehan	1910-1911	New York, N. Y.
41.	S. F. Fullerton	1911-1912	St. Louis, Mo.
42.	Charles H. Townsend	1912-1913	Denver, Colo.
43.	Henry B. Ward	1913-1914	Boston, Mass.
44.	Daniel B. Fearing	1914-1915	Washington, D. C.
45.	Jacob Reighard	1915-1916	San Francisco, Calif.
46.	George W. Field	1916-1917	New Orleans, La.
47.	Henry O'Malley	1917-1918	St. Paul, Minn.
48.	M. L. Alexander	1918-1919	New York, N. Y.
49.	Carlos Avery	1919-1920	Louisville, Ky.
50.	Nathan R. Buller	1920-1921	Ottawa, Canada
51.	William E. Barber	1921-1922	Allentown, Pa.
52.	Glen C. Leach	1922-1923	Madison, Wis.
53.	George S. Embody	1923-1924	St. Louis, Mo.
54.	Eben W. Cobb	1924-1925	Quebec, Canada
55.	Charles O. Hayford	1925-1926	Denver, Colo.
56.	John W. Titcomb	1926-1927	Mobile, Ala.
57.	Emmeline Moore	1927-1928	Hartford, Conn.
58.	C. F. Culler	1928-1929	Seattle, Wash.
59.	David L. Belding	1929-1930	Minneapolis, Minn.
60.	E. Lee LeCompte	1930-1931	Toronto, Ontario

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PART I

BUSINESS SESSIONS

TRANSACTIONS
of the
AMERICAN FISHERIES SOCIETY
SIXTIETH ANNUAL MEETING
at
Toronto, Ontario
August 27, 28, and 29, 1930

The Sixtieth Annual Meeting of the American Fisheries Society was held at the Royal York Hotel, Toronto, Ontario, August 27, 28, and 29, 1930.

Registered Attendance

Attwood, C. H., Deputy Min. of Mines and Nat. Resources, Winnipeg, Man.
Avery, Carlos, 2273 Woolworth Bldg., New York, N. Y.
Belding, David L., Boston University School of Medicine, Boston, Mass.
Bell, G. S., Ont. Club, Toronto.
Bellisle, J. A., Dept. of Fisheries and Game, Quebec, Que.
Berg, George, 1702 East 12th St., Indianapolis, Ind.
Bostick, H. G., 351 California St., San Francisco, Cal., Dupont Powder Co.
Bradford, Ralph F., Springfield, Ill.
Bradford, Mrs. R. F., Springfield, Ill.
Bradford, R. F., Jr., Springfield, Ill.
Breyfogle, Peterborough, Ont.
Briggs, Arthur, Winthrop, Maine.
Brown, Dell, Mammoth Spring, Ark.
Buller, Nathan R., Commissioner of Fisheries, Harrisburg, Pa.
Byers, A. F., 1226 University St., Montreal, Que.
Candee, C. N., 47 Yonge St., Toronto, Ont.
Catt, Jas., Dept. of Fisheries, St. John, N. B.
Chute, Walter H., Shedd Aquarium, Grant Park, Chicago, Ill.
Clark, Gregory, Toronto Daily Star, Toronto, Ont.
Cobb, E. W., State Bd. of Fisheries and Game, Hartford, Conn.
Cook, A. B., Jr., Dept. of Conservation, Lansing, Mich.
Cox, H. G., Dept. of Game and Fisheries, Toronto, Ont.
Crowell, Mary, Shortsville, N. Y.
Culler, C. F., U.S. Fisheries Station, La Crosse, Wis.
Davidson, Walter, 180 Duke St., Toronto, Ont.
Davis, H. S., U. S. Bureau of Fisheries, Washington, D. C.
Detwiler, John, University of Western Ontario, London, Ont.
Devlin, Miss M. B., Dept. of Colonization, Game and Fisheries, Quebec.
Dignam, H. J., Dept. of Game and Fisheries, Toronto, Ont.
Dymond, R., Jr., University of Toronto, Toronto, Ont.
Embody, G. C., Cornell University, Ithaca, N. Y.
Etter, A. E., Regina, Sask.
Farrington, J., Dept. of Game and Fisheries, Toronto, Ont.
Feitz, Earl, Dupont Co., Detroit, Mich.
Field, George W., Sharon, Mass.
Follett, Richard E., Detroit Zoological Society, Detroit, Mich.
Généreux, Miss Arline, Prov. Sec. Dept., Quebec, Que.
Gibaut, F. M., Dept. of Game and Fisheries, Quebec, Que.
Gordon, Seth, Izaak Walton League, Chicago, Ill.
Harkness, Wm. J., University of Toronto, Toronto, Ont.
Harrison, Eugene, Dupont Co., Wilmington, Del.
Hayford, Chas. O., Hackettstown, N. J.
Heard, R. D., Dept. of Game and Fisheries, Toronto, Ont.
Heinzerling, C. H., Creek Chub Bait Co., Garrett, Ind.
Helmer, A., Calgary, Alta.
Heyward, Zan, Dupont Co., Columbia, S.C.
Hoofnagle, G. W., Charlevoix, Mich.
Hubbs, Carl L., Ann Arbor, Mich.
Huntsman, Dr. A. G., University of Toronto, Toronto.
James, Emerson, Fort Henry, N. Y.
James, Mrs. Emerson, Fort Henry, N. Y.
James, M. C., Bureau of Fisheries, Washington, D. C.
Jessop, Miss, Montreal, Que.
Johnson, M. S., University of Minnesota, St. Paul, Minn.
Jull, T. W., Toronto, Ont.
Laird, Jas. A., Sup. of Fisheries, South Side Sportsmen's Club, Oakdale, Long Island.
LeCompte, E. Lee, State Game Warden, Baltimore, Md.
Lincoln, Guy, Oden, Mich.
Lindsay, R. C., Dept. of Colonization, Mines and Fisheries of Quebec, Gaspe, Que.
Lord, Russell N., Pittsford, Vt.
Lucas, G. H. W., University of Toronto, Toronto, Ont.
MacKay, H. H., Dept. of Game and Fisheries, Toronto, Ont.
Marks, J. P., Paris, Mich.
Marsh, Miss E. L., Clarkesburg, Ont.

McDonald, D., Dept. of Game and Fisheries, Toronto, Ont.
McLeod, A. W., Dept. of Game and Fisheries, Toronto, Ont.
Meredith, C. J., Kentucky Game and Fish Com., Frankfort, Ky.
Meredith, Mrs. C. J., Frankfort, Ky.
Miles, Lee, Little Rock, Ark.
Miller, A. P., Bemus Point, N. Y.
Moore, Dr. Emmeline, State Conservation Dept., Albany, N. Y.
Munro, Jas. A., Okanagan Landing, B. C.
Needham, R. R., Rochester, N. Y.
Norton, R. G., Bemus Point, N. Y.
Nully, Harry, Searcy, Arkansas.
Otterson, John, Dupont Co., Wilmington, Del.
Palmer, C. M., Jr., Dupont Co., Wilmington, Del.
Pentland, Ernest, University of Toronto, Toronto, Ont.
Poole, E. G., C. N. R., Montreal, Que.
Powell, A. M., Baltimore, Md.
Richard, L.A., Deputy Min. of Game and Fisheries, Quebec, Que.
Richer, William, University of Toronto, Toronto, Ont.
Rickord, M. K., General Manager, Izaak Walton League, Chicago, Ill.
Ritchie, H. H., Chief Game Warden, Fredricton, N. B.
Robertson, A. W., Lexington, Va.
Rowe, W. A., West Buxton, Maine.
Schuil, Henry A., Grand Rapids, Mich.
Shirts, Walter, 124 State House, Indianapolis, Ind.
Slautterback, J. J., Harrisburg, Pa.
Smith, P. W., Dept. of Game and Fisheries, Toronto, Ont.
Smith, Charles F., Chief Deputy Game Warden, State of Maryland, Baltimore.
Snipes, F. L., Northvale, Mich.
Snyder, J. P., Cape Vincent, N. Y.
Stobie, George J., Augusta, Me.
Surber, E. W., Tremperleau, Wis.
Surber, Mrs. E.W., Tremperleau, Wis.
Surber, T., Game and Fish Dept., St. Paul, Minn.
Taillon, Louis, Gracefield, Que., Supt. Gatineau Fish and Game Club.
Taylor, Dr. C. B., St. Thomas, Ont.
Tucker, George, Gilmer, Texas.
Tucker, W. J., Austin, Texas.
Taylor, B. W., Dept. of Colonization, Mines and Fisheries, Montreal, Que.
Van Oosten, John, 1020 Michigan Ave., Ann Arbor, Mich.
Webster, B. O., State Capitol, Madison, Wis.
Webster, Mrs. B. O., Madison, Wis.
Westerman, Fred A., Dept. of Conservation, Lansing, Mich.
Werner, W. H. R., Dept. of Game and Fisheries, Toronto, Ont.
Wheeler, Charles E., Com. of Conn., Stratford, Conn.
White, E. F. G., Dupont Co., Ottawa, Ont.
Wicks, Judson L., Minneapolis, Minn.
Wicks, Mrs. Judson L., Minneapolis, Minn.
Wilton, Margaret, Dept. of Game and Fisheries, Ontario.
Woodward, C. C., Tallahassee, Fla.
Woodward, Mrs. C. C., Tallahassee, Fla.
Young, E. C., House of Commons, Ottawa.
Young, Floyd S., Lincoln Park Aquarium, Chicago, Ill.

BUSINESS SESSIONS

The meeting was called to order by President David L. Belding at 10:00 A.M. Wednesday morning, August 27, 1930.

Addresses of welcome were delivered by Hon. Charles McCrea, Minister of Mines, Game and Fisheries, Ontario, and by Comptroller Robbins, representing Mayor Wemp of the City of Toronto. Acknowledgment of these addresses of welcome was made by the President.

REPORT OF THE SECRETARY-TREASURER

CARLOS AVERY

To the Officers and Members of the American Fisheries Society:

During the past year no special campaign for new members of the Society has been carried on by any of the officers. Notwithstanding that, fifty-five new members have been added. There has been a net loss, however, during the year of seven members, eleven having resigned, eight members having died and forty-three having been dropped for non-payment of dues. Four active members have been transferred to the life membership list under that provision of the by-laws which permits such transfer of members who have paid dues as active members for not less than twenty-five years.

Owing to the necessity of securing the printing of the transactions in ordinary commercial channels, the expense of such publication has been greater this past year than for several years. Notwithstanding this increased expense, however, the treasury retains a larger balance than last year.

There has been an increase of $205.36 in the permanent fund of the Society, from interest, which now amounts to $4,206.27.

All the transactions of the Society from its beginning are now indexed, the index for the last volume being included therein. The indices to the first fifty-eight volumes are bound separately and are for sale.

The financial transactions for the Society for the year were as follows:

AMERICAN FISHERIES SOCIETY

Treasurer's Report

GENERAL FUND

Receipts

Balance on hand at meeting of 1929		$ 633.51
Annual Dues		
Individuals and Libraries		
For the year 1927	$ 9.00	
1928	105.25	
1929	1,246.42	
1930	69.00	
Clubs and Dealers		
For the year 1928	40.00	
1929	165.00	
State Memberships		
For the year 1928	20.00	
1929	160.00	
1930	10.00	
Sale of Transactions	358.00	
Sale of Separates	89.90	
Sale of Index-Catalogue	195.50	
American Game Protective Assn. Memb. & Trans.	5.50	2,473.57
		$3,107.08

Disbursements

	Voucher No.		
1929 Meeting, Minneapolis, Minn.			
Reporting Proceeds of	34	$295.00	
Cards printed for meeting	27	3.00	$298.00
Transactions—1929—Vol. 59			
Printing	48	1,101.77	
Mailing jackets for	42	9.50	
Cuts	40	8.31	
For zinc etching—Charts	38	15.63	
Postage for mailing of	51	48.02	
Printing Separates	49	177.48	
Separates 1928 meeting	28	11.43	
Separates 1928 meeting	33	16.45	1,388.59
Index—Catalogue			
Indexing Vol. 59	44	14.00	14.00
Postage, Express, Telegrams			
Secretary-Treasurer's office	36	10.20	
" " "	46	69.23	
Librarian's office	32	8.24	
" "	37	10.00	97.67
Clerical Assistance, Secretary-Treasurer's Office			
1928–1929	29	144.00	
1929–1930	50	150.00	294.00
Premium on Treasurer's Bond	30	2.50	2.50
Exchange on Checks (vouchers attached to Bank Statements)		9.60	9.60
Refund—Duplicate check (H. Jensen)	31	3.00	
" American Game Prot. Assn.	39	5.50	
" American Game Prot. Assn.	41	.50	9.00
Printing, Stationery, Circulars, etc.	35	22.50	
" " " "	43	20.58	43.08
Checks Nos. 45 and 47 cancelled and reissued in order to classify items			
			$2,156.44
Receipts—General Fund		$3,107.08	
Disbursements—General Fund		2,156.44	
Balance on hand August 23, 1930			950.64

PERMANENT FUND

Cash balance on hand, 1929 meeting	$1,000.91	
Interest in Savings Account received (bank)	9.50	
Interest on Trust Company Certificates	195.86	
Total in Savings Account	$1,206.27	
Certificate Title Guarantee & Trust Co. purchased	1,000.00	
Cash balance in Savings Account		$206.27
Certificates Title Guarantee & Trust Co.		4,000.00
Total		$4,206.27

The report of the Secretary-Treasurer was received and referred to the Auditing Committee. Upon the approval of that committee it was later accepted by the Society.

REPORT OF LIBRARIAN

JOHN W. TITCOMB

The principal functions of the Librarian consist in caring for all surplus copies of the Transactions and in promoting their distribution by sale. There is a steadily increasing demand for complete sets of the publications from libraries, or for sets covering the past thirty years.

The first meeting of the Society, when it was known as the American Fish Culturists Association, was held in 1870. The library has no printed publications of the Transactions until 1876 and lacks copies for its own files covering the years—

1877	1881	1902
1878	1882	1903
1879	1883	1905
1880	1887	

The Librarian would like to secure copies of all the above for the permanent files of the Society, and in addition to those needed for the permanent files, it would be advantageous to have copies available to complete sets for libraries. In addition to those needed for the permanent files there are no copies available for distribution or sale covering the years 1899 and 1900. We have an ample number of copies of the Transactions covering all dates, other than those already mentioned, to meet the demands of those who are collecting sets or want to refer to some individual publication. The demand for Volume Thirty-one for 1905 would seem to warrant reprinting a limited edition.

It has been found that in many States the laws do not permit the Commissioners of Conservation to subscribe to membership in the Society, but it is usually possible for the Commissions to buy the Transactions for issuance to their fish culturists. Strange to say, there are many States whose fish culturists do not have access to these publications, and apparently the Commissioners do not appreciate the fact that it is only through these publications that one can keep up with the times in all matters pertaining to fish culture and relevant subjects.

Every reader of this report is urged to impress upon those interested in the objects and aims of the Society the advantages derived from being identified with it.

Those who are not interested in retaining the published Transactions or who run across any of the older publications can render a service to the Society by turning them in, either as a gift or, if they have a volume of which the Society is short, with the expectation of proper compensation.

REPORTS OF VICE-PRESIDENTS OF DIVISIONS

REPORT OF DIVISION OF FISH CULTURE

CHARLES O. HAYFORD

In presenting a report to the Society from the Division of Fish Culture, I want to point out the importance of well-trained fish culturists. In the pioneer days, when most of the fish were planted at a small size, it did not require the skill and knowledge it does to raise and carry large fish through the hot summer months.

In States where the sportsmen demand the planting of large fish, they take an active interest in the hatchery operations and the physical condition of the trout planted.

Most of our fish culturists have a good knowledge of the taking of spawn, hatching and raising the young fish up to a size of three to four inches.

It has been interesting to note the number of fish culturists visiting our hatchery who cannot use a microscope or have no knowledge of the effects of parasites on fish.

I think it is just as necessary for a fish culturist to be able to use a microscope as it is to know how to take spawn. Recognizing and eliminating parasites is not as difficult as it seems. We have a young lady in our office who does practically all of the microscopic work in our plant and she has had no scientific training for this line of work. She readily recognizes all the different parasites and diseases that affect our fish.

Every fish culturist should have Dr. Davis' pamphlet "Care and Diseases of Trout," Document No. 1061, published by the U. S. Bureau of Fisheries. With all due respect to previous writers, I think this is the most valuable book that has ever been written on the subject, to the practical fish culturist.

In his last year's report as Vice-President of the Division of Aquatic Biology and Physics, Dr. Davis covered the subject of pond culture. I do not hesitate to say that the demand for larger pond fish is going to be as great as it is for trout. In order to carry a supply of large fish through the hot and dry summer months with a reasonable certainty, fish culturists of today must have a thorough working knowledge of the different factors that increase or decrease the finny family.

In conclusion, let me say, in my judgment, it is better to spend a few hundred dollars in equipping and training a fish culturist than to lose thousands of dollars' worth of fish through inability to recognize the cause and lay it to anything from the housemaid's knee to heart failure.

REPORT OF THE DIVISION OF ANGLING

FRED A. WESTERMAN

In offering this report for the Division of Angling I need not remind you that a very considerable amount of the effort, energy, and funds expended by the various agencies interested in the propagation of fish is devoted to promoting sport fishing or

game fishing as distinguished from commercial fishing or hatcheries producing fish for market purposes. And even the commercial fisheries have a considerable interest in sport fishing since the sale of eggs and live game fish is an important source of revenue.

I venture to say that in no other country is there so great a percentage of the population engaged in fishing for recreational purposes or as a source of food supply for the family dinner table as on the North American continent.

Faster and better transportation facilities have made it possible for anglers to reach streams and lakes once inaccessible or accessible to but a few. As a result, the area in which satisfactory fishing is to be maintained has expanded. Advanced agricultural and industrial development has brought its attendant problems of stream pollution and has greatly changed stream conditions. The lure of the out-of-doors is annually appealing to greater numbers, with a consequent increased toll on the fish supply.

As a result of these many and varied problems, Dominion, Provincial, Federal and State Governments are today actively engaged with constantly increased programs to keep pace with present demands.

The tendency among fish culturists generally is to develop our hatchery reared fish to a larger size, even to legal size in a number of states, before releasing them into suitable waters.

We are undertaking intensive and extensive research work to unlock more of nature's aquatic secrets.

We are striving for regulations that will permit a maximum natural reproduction in our public waters.

We are securing statistics better to gauge the trend of the fisheries.

We are assembled here to discuss our mutual problems.

The reason for all this is, chiefly, to promote better fishing, or as President Hoover has so aptly put it, "To reduce the time between bites." Also, that we may use and yet conserve the supply so those who follow may know the rare joy which can be found only in the pursuit of angling. I believe it should be one of the aims of this society to make it possible for every boy and girl to have the opportunity of enriching memory with this delight of childhood which loses none of its charm through the later years of life.

It is no primrose path that we tread. There are many problems demanding our sincere thought and united effort. The encroachment of private interests by acquisition of waters heretofore accessible to the angling public is an acute problem becoming more pressing each day.

Experience of the past, with the progress made to date, gives every encouragement that we can enjoy our heritage of angling and endow the future with this pleasure that has been shared by the countless numbers of those gone before,—who have lived and experienced a fuller and richer life for having had the opportunity to angle.

The quest for success in angling by people seeking outdoor recreation is well illustrated by the experience of an old darky who rented boats and equipment on the lake. Upon being addressed with the inquiry where the best fishing on the lake was to be had, he replied, "Ah don't just know. The people from this side go to the other side to fish,—the people from the other side come to this side to fish. The best fishing am always found where you ain't."

REPORT OF THE DIVISION OF COMMERCIAL FISHING

Percy Viosca, Jr.

I hereby submit as a report of the division of Commercial Fishing, a few observations on some commercial fishery problems which I believe are worthy of your serious consideration.

Excepting at the Seattle meeting, it seems that seldom over 15% of the papers presented before the meetings of this society deal with or have a direct bearing on commercial fishery problems. While I do not wish to convey the impression that cultivation of and scientific research dealing with game fish and other non-commercial species are any less important to the welfare of our country, I do believe that the problems of the commercial fisheries are important enough to deserve more consideration in the deliberations of this society.

The Angler vs. the Commercial Fisherman

In those states blessed with an abundance of fish life, there seems to have been a constant battle between the commercial fisherman and the angler, with the commercial fisherman yielding little by little until today the sale of game fish is prohibited in nearly every state of the Union. This is as it should be, and results in the greatest good for the greatest number.

This prohibition is especially important in states with relatively small streams and lakes, for in such states there can be no question that conserving the fish for the anglers is by far the best use to which they can be put, and commercialization would result in rapid depletion. But let us inquire as to whether or not the angler can encroach too much upon the rights of the commercial fishermen to the detriment of the public welfare? "The public welfare be damned" seems to be the motto of the over ardent or selfish angler, and little can be done to enlist his aid in protecting the rights of the commercial fisherman unless it can be shown that the two go hand in hand, and that unless a program of co-operation can be worked out, the angler's own sport is surely doomed.

It is often the commercial value of the fish therein that saves our lakes from being drained for agricultural or real estate exploitation, and incidentally saves the game fish as well. It is often the pressure brought to bear by commercial fishing interests that saves our streams from destructive pollution. When intangible sport and recreational values, enormous though they be, fail to move a legislature to action, the easily measured, though sometimes less valuable, commercial fishing industry often saves the day for the sportsman as well. It is the valuable muskrat and commercial fishery resources that are saving the last large areas of marshland in America from other exploitation, and thus incidentally saving our best game fish and waterfowl refuges.

In Louisiana and some other states, commercial fishing licenses pay the bulk of the bill for fish conservation. The commercial fishing interests, often well represented in our legislatures, are voluntarily taxing themselves to save the game fish as well as their own industry. Such a condition, of course, can only exist in states which have a relatively important commercial fish industry.

Little seems to be known of the competitive relationship of game and commercial fish. To illustrate my point, I will relate an experience in my own State. A number of lakes abounding in game fish had been closed a few years ago by police jury action, against all forms of commercial fishing, supposedly to protect the game fish from the

depredations of the fishermen. There was little poaching as the anglers saw to that themselves, but there was a very noticeable decline in game fish each succeeding year until soon angling was hardly worth while. Upon investigation, I found that the shallows in these particular lakes were largely devoid of all but microscopic vegetation. Turtles were superabundant everywhere, and the lakes were overrun with large buffalo-fishes, gars, and in some cases, carp and carp suckers. The anglers had removed only the game fish, leaving their competitors and enemies to breed and grow unmolested.

We soon initiated a plan whereby the commercial fishing rights were leased to responsible fishermen and the funds thus provided used to pay a special warden, and otherwise to improve both game and commercial fish'ng. As much as 200 pounds of coarse or marketable fish per acre per year were removed from some waters, without injury to the game fish, yet even a greater poundage of the young of the valuable commercial species, than above reported, was returned alive to the waters, not counting that which escaped through the meshes. I recommend such a plan wherever feasible in all but the larger lakes, instead of free lance fishing, since it settles the war between the angler and the commercial fishermen in a way immensely profitable to both, by restoring and maintaining a normal balance in the waters between the game and commercial species.

Certainly more thought and study should be devoted by members of this Society to the ecological relationships of game and coarse species, particularly such forms as carp, suckers, and bullheads which may dominate waters otherwise admirably suited to the development of an abundant game fish fauna. Prohibiting the seining of the coarse species, or the planting of innumerable fry and fingerlings of game species will certainly not restore the balance in favor of the game fish. A well-regulated commercial fishery working hand in hand with the anglers and their game fish restoration program is the only answer.

Hasty or Ill-advised Legislation

The Louisiana act permitting police juries to control certain lakes, without biological knowledge or advice, was certainly ill-advised, and I believe that in most cases, no legislation at all is better than hasty or poor legislation. I might cite another example of protective legislation which is destroying its own ends. Some years ago a uniform minimum size limit of sixteen inches was placed on all fresh water catfish taken for commercial purposes in Louisiana. In spite of this legislation there seems to have been a gradual decline in the number of large catfish taken annually, the poundage, which represents the potential production of our waters, remaining about the same but fish of smaller and smaller average size being taken. Incidentally a decided change in the relative abundance of the different species seems to have taken place. Bullheads and eel cats, which grow very little larger than the 16 inch size limit, have become superabundant, whereas the large species have been gradually disappearing. The law gives relatively greater protection to these two less desirable species, and competition for the limited food supply does the rest.

Size Limits and Mesh—Closed Seasons and Closed Zones

Because of the great variety of our North American fisheries and the many peculiar local problems, it is difficult to make recommendations as to the size of the mesh. If the mesh size would solve the size limit problem, all would be simple. Sometimes a large

mesh does more harm than a smaller one, because of the gilling of undersized fish, or those of another species, which could otherwise be released alive. Sometimes a larger mesh permits the escape of smaller destructive competitors of game or commercial fish, and it were better to use a smaller mesh and dispose of these, even if it were done at the expense of the occasional loss of an individual of a more valuable commercial or game species.

In regard to seasons and zones, I, for one, viewing the matter largely from conditions applying in my own State, where there is plenty of water and plenty of breeding stock in that water, have always advocated size limits and closed zones in preference to closed seasons on the commercial species, which are all prolific spawners. The zones are not intended chiefly to protect a sufficient percentage of the breeding stock, but the growing young as well. In order to make room for a superabundant new generation, the larger percentage of the adults, up to a safe point, must be removed from the waters, and often this can only be done advantageously or profitably during the breeding season. By having a size limit which permits each species to spawn at least once before being taken, the factor of safety will be on the side of the species. The closed season and closed zone idea, combined with a reasonable size limit, all designed to protect the growing young and not the adult, has been in force in Louisiana on salt water shrimp for a long period of years, during which time there has been a steady rise in production.

On some fresh water species, especially the softer meat varieties, a summer closed season, especially for protecting the younger generation, would be an advantage. At this time spoilage is high, and the markets often glutted with both fresh and salt water species. Such protection would have an economic as well as a biologic value.

Besides, the danger of destroying game fish or the young of commercial species, by roiling of the water and stirring up sediment, or by gilling of the fish, is always negligible during the cooler months of the year, whereas it is a serious factor in warm water and causes many of the justified complaints against commercial fishing. I believe the poundage per acre per year, the true measure of production, will be greater with many commercial species, with a summer closed season, than with a closed season during the spawning period.

Flexibility of the Individual Fisherman

An important conservation measure is often overlooked in the eagerness of legislatures to tax each different type of tackle or fishery. We should strive for a uniform commercial fisherman's license so that each fisherman can cease fishing the thing which is scarce for that which is plentiful without purchasing an additional license. Three years ago there were some forty odd classes of commercial fishing licenses in Louisiana. In one legislative enactment they were cut to twelve and can easily be reduced further without decreasing revenues. The average fisherman is not in a position to gamble on the fluctuations of the different fisheries, and can ill afford to take out all classes of licenses.

Uniform Laws

While striving for simpler and more uniform state laws, we should also strive for uniform laws on lakes or streams bordering two or more States or countries. Of course it is impractical for each State in the Union to have laws identical with those of all its

neighbors, as I have seen advocated. To do that would be to abolish the States. Kansas, for instance, would like to see all States of the valley declare catfish game species and prohibit their commercialization. For Louisiana to do that, would be to destroy not only her valuable commercial fisheries but her wonderful bass fishing as well, for the catfish would soon dominate everything. The same laws that would apply admirably to a State with as little water as Kansas, cannot be applied in Louisiana with her millions of acres under water. However, where an important border lake or community fishery is concerned, special uniform laws pertaining only to that lake or that fishery could be adopted by the two or more governments by agreement.

Legislation vs. Engineering

When it is not possible to legislate a vanishing species back into existence, often a simple engineering feat will do the trick. Fisheries depleted by lowered water levels due to drainage projects and channel dredging can be restored only by dams. Fluviatile species such as the buffalofishes, the fresh water drum, and the paddlefish, decrease in the Mississippi Valley during every drouth but are restored again without legislation with every flood. These fish, which evidently cannot spawn effectively in certain lakes when divorced from the rivers by levees, are restored with every flood or crevasse. No laws will bring them back except such as will permit the construction of floodways or sluices of some kind to permit an annual influx of that type of water necessary for their spawning conditions.

This suggests the matter of tying in the matter of flood control with fisheries restoration, which subject I dealt with fully in my paper which appeared in the 1927 transactions of this Society.

Biological and Statistical Research

It is almost needless to stress before this Society the value of biological and statistical research to the commercial fisheries. The bureau of fisheries and many States are working in the right direction. Much more of course needs to be done as we have barely scratched the surface. The age, rate of growth, and size at maturity of most of our commercial species are still unknown, while with the game species our knowledge along these lines is fairly complete. The knowledge gained by biological and statistical surveys is the best means with which to unite dissenting factions among anglers or fishermen, in lobbies or legislatures.

Commercial Fish Culture

Except in the case of trout, the conditions of existence of which permits intensive cultivation, commercial fish culture in this country has not come into its own, as in China, Japan, and some European countries. The high price of labor and supervision, when compared with the relatively low cost of securing the natural supply, has been the chief factor against it. Nevertheless, there is reason to believe that fish farming of commercial and warm water game fishes will eventually come into its own in this country as trout culture has already done. There are certainly far greater areas and a greater variety of conditions available in this country for the culture of warm water species than there are for trout. Included with them, or as separate projects, might be considered the cultivation of the bullfrog.

There seems to be considerable opposition among sportsmen and conservationists in some States, Louisiana included, to permit the sale, for consumption, of game fish, particularly bass and sunfish, bred and reared in captivity. There is great fear that permitting such would be a subterfuge to let down the bars altogether. I have eaten captive raised trout legally in a number of States where the sale of wild trout is strictly prohibited and rigidly enforced. A fish farm is a rather conspicuous affair, easily supervised, and no business man would jeopardize such a commercial project for the little money there might be in bootlegged fish. In my opinion the well-regulated bass farm will take away the motive for fish bootlegging, for no one will buy a fish of doubtful quality illegally if he can secure one of high quality legally and at a satisfactory price. To sell at a satisfactory price they must be reared in such large quantities that considerable funds are required to finance the outlay, and such capital cannot be jeopardized by illegal or shady transactions. With captive raised game species legally on the market, the motive for the sale of their wild brothers will cease to exist.

APPOINTMENT OF COMMITTEES

Auditing: C. O. Hayford (Chairman), F. A. Westerman, W. J. K. Harkness.

Nominations: G. W. Field (Chairman), G. C. Embody, E. Moore, E. Cobb, A. Clapp.

Resolutions: L. Miles (Chairman), H. S. Davis, J. A. Rodd, J. Wicks, A. G. Huntsman.

Time and Place: J. W. Titcomb (Chairman), W. J. K. Harkness, G. W. McCullough, C. O. Hayford, S. Gordon, G. J. Berg, C. J. Meredith.

Special Committee on Communications to Professor Prince and Mr. Chambers: C. Avery (Chairman), D. MacDonald, G. C. Embody.

REPORTS OF COMMITTEES

COMMITTEE ON RELATIONS WITH FOREIGN AND STATE GOVERNMENTS

Mr. Rodd: While in the absence of our Chairman, Mr. Radcliffe, I have no formal report to present, I shall endeavor to outline certain developments of the past year. The various commissions on the halibut, the Pacific salmon, and the Great Lakes and the North American fishery investigations have made considerable progress. In addition, an international commission was appointed during the past year to investigate the fisheries of Lake Champlain and contiguous waters. It is a fact-finding commission, which has been established for the purpose of settling the long-standing Missisquoi Bay question.

The Halibut Commission is studying the halibut fishery of the north Pacific. I believe that the treaty has been renewed for another term. A treaty has been signed by the Secretary of State and the Canadian Minister at Washington regarding the sockeye salmon, but it has not become effective. The international Pacific salmon investigation commission was established in 1925, and is holding regular sessions. It is an informal organization of the leading fishery executives of the United States and

Canada, the Pacific States and British Columbia and Alaska. It had a very successful meeting in California a few weeks ago. Some of you are more or less familiar with the situation in the Great Lakes. Investigations and international discussions have been going on, which I believe will lead eventually to uniform regulations. The North American committee on fishery investigations had a meeting in Ottawa last autumn.

Mr. Avery: The present policy of the United States and the Canadian governments is to deal with these various international questions each one by itself instead of trying to settle all in one treaty. A treaty, you will remember, was entered into between the United States and Canada twenty years ago, but it never became effective because, owing to opposition on the part of commercial fishing interests, it was not ratified by the United States Senate. Therefore it seemed more effective to deal with each problem in a separate treaty. Some of these questions have already been settled, as Mr. Rodd has reported, by the consummation of treaties, and others will be dealt with in the course of time.

Report of the Auditing Committee

Mr. Hayford: The Auditing Committee has checked the books and vouchers of the treasurer and finds the report of the treasurer to be correct.

We recommend that the sum of $150 be allowed the secretary-treasurer for clerical assistance during the year 1930 to 1931.

The adoption of the report was moved and carried.

REPORT OF THE SPECIAL COMMITTEE ON THE COMMUNICATIONS TO PROFESSOR PRINCE AND MR. CHAMBERS

Mr. Avery: Pursuant to the instructions received, the committee sent a message to Professor Prince and Mr. Chambers reading as follows:

> The officers and members of the American Fisheries Society, in convention assembled at Toronto, by resolution extend cordial greetings and regret your inability to attend this meeting. We earnestly hope you will soon be completely restored to health and to your usual activities, and assure you of the highest regard and warmest esteem of the entire membership of the Society.

The report of the committee was adopted.

Committee on Time and Place

Mr. Titcomb: Following the precedent of past years, a committee of the organization met ahead of time in order to be able to confer with the committee of the organization first assembling, the International Association of Game, Fish and Conservation Commissioners. Invitations had been received from all over the United States. Florida made a very strong bid. A very cordial welcome was extended by Maryland, from a great many different sources. Mr. LeCompte presented the invitation in person, reinforced by the representative of the Chamber of Commerce. However, the arguments presented by Judge Lee Miles, of the International Association, and also a member of this Society, seemed to prevail, and the two committees recommended that the next meeting be held at Hot Springs, Arkansas, the time to be set by the executive committees.

The report was adopted unanimously.

COMMITTEE ON RESOLUTIONS

Fraser River Salmon Fisheries

Whereas, further delay in the settlement of the problems connected with the Fraser River sockeye salmon run and the salmon fisheries of Puget Sound is continuing to jeopardize the welfare of this important commercial fishery;

Be It Resolved, that the American Fisheries Society urge early consideration and ratification of the Sockeye Salmon Treaty with Canada now pending before the United States Senate.

National Park Standards

Be It Resolved that this organization endorse the declaration of National Park Standards in the United States as devised and adopted by the Camp Fire Club of America in its statement entitled "National Park Standards," of April, 1929.

Regulation of Public Waters at the Source

Whereas, experience provides us with knowledge that the purity and quantity of water is of primary importance to the national food supply and to public facilities for recreation, both terrestrial and aquatic; and

Whereas, floods and droughts in many places are but symptoms and evidence of human neglect of proper engineering and biologic precautions, in our economic treatment of the public waters;

Be It Resolved, that the American Fisheries Society urges upon Federal Government, Provincial, State legislatures, corporations and the general public an increasing co-operation between the engineering and the biologic sciences and between municipal business and biologic practices, for the purpose of making the public waters better conditioned for this normal function in nature; and particularly at present to develop methods which shall increase the usefulness of water, by improved distribution, through such regulations of the run-off water as shall lower the crests of floods, and raise the low water levels, in rivers, and of the water tables where needed.

Water Pollution

Whereas, the pollution of our lakes and streams is one of the greatest enemies of fish life, and

Whereas, with the growth of the population and industry the contamination of our public waters is, year by year, increasing both in inland streams and lakes and the coastal waters, and

Whereas, the science of sanitation offers in the case of domestic sewage, and most industrial kinds, a practical and reasonable economic method of treating the same so as to prevent serious pollution;

Be It Resolved, that it is the sense of this meeting that all communities and all industries should be urged to install plants for the treatment of their liquid waste;

Be It Further Resolved, that the Izaak Walton League of America and all other organizations engaged in warfare against pollution of inland streams and lakes and the coastal waters, be, and the same hereby are, extended the hearty encouragement of this Society.

Oil Pollution

Whereas, the menaces to aquatic life, both in coastal and inland waters, from mineral oils entering these waters has become exceedingly serious, adversely affecting national assets, of recreation and food supply, and of business interests;

Therefore Be It Resolved, that we hereby memorialize Congress to further co-operative efforts to regulate and to prevent the entrance of mineral oils from every practicable source into all waters, within international, state and federal jurisdictions, to the end that all public and private interests may be safeguarded against the results of wastage of mineral oils, in small and large quantities, whether from preventable accidents or negligence of individuals and of corporations; and

Be It Further Resolved, that as a necessary step in this direction we endorse H.R. 10625.

Impounding Dam Studies

We deplore the destruction of fishery resources which often results from the erection of water impounding dams, and urge that the effect of all such projects be given careful study by government fisheries experts before construction is undertaken in order that unwise projects may be averted and that in every case where dams are built plans may be made to offset the effect of their construction upon fish life.

We pledge our co-operation in the movement recently launched by the Izaak Walton League of America to have federal and local water impounding laws amended to assure such studies.

Enforcement of the Black Bass Law

Whereas, the black bass is recognized as one of North America's most desirable game fishes, and

Whereas, a Federal Act known as the Hawes Black Bass Law was passed by Congress of the United States in 1926 in an effort to stop inter-State traffic in these fishes, and

Whereas, the present law provides no machinery for the enforcement of this Act, with the result that many tons of these game fishes find their way to the markets in various States,

Therefore Be It Resolved, that the American Fisheries Society in convention assembled on this 28th day of August, 1930, strongly urges the early enactment of the Hawes Bill providing for adequate funds and for the enforcement of the Act of 1926 which is now pending before Congress in order that the Hawes Act may be made more effective,

Be It Therefore Resolved, that we urge all States to enact laws prohibiting the taking and selling of black bass or other game fishes except for propagation or scientific purposes, regardless of where they are taken.

Acknowledgment of Courtesies

Resolved, that we express our sincere appreciation for the attractive programme which has characterized the Sixtieth Annual Meeting of the American Fisheries Society to the Department of Game and Fisheries of the Province of Ontario;

Be It Further Resolved, that we extend our sincere thanks to Honourable Charles McCrea, and to Mr. D. McDonald, Minister and Deputy Minister respectively, for their efficient services rendered in the form of entertainment, programmes, clerical services, and other courtesies, and especially for the most excellent lunch served, together with tickets to the Canadian National Exhibition, and transportation to same;

We also express our appreciation to the Toronto newspapers for the publicity given the meeting;

We also express our appreciation to the Royal York Hotel for the many courtesies extended which have contributed greatly to the comfort and pleasure of our members and to the success of this Convention.

The adoption of these resolutions was carried unanimously.

COMMITTEE ON NOMINATIONS

Dr. Emmeline Moore presented the report of the Nominating Committee, as follows:

For President, E. Lee LeCompte .... Baltimore, Md.
Vice-President, J. A. Rodd .... Ottawa, Ont.
Secretary-Treasurer, Carlos Avery .... New York, N. Y.
Librarian, John W. Titcomb .... Hartford, Conn.

Vice-Presidents of Divisions

Fish Culture, M. C. James . . . . Washington, D. C.
Aquatic Biology and Physics, W. J. K. Harkness . . . . Toronto, Canada
Commercial Fishing, Clarence Birdseye . . . . Gloucester, Mass.
Angling, Fred A. Westerman . . . . Lansing, Mich.
Protection and Legislation, I. T. Quinn . . . . Montgomery, Ala.

Executive Committee

H. S. Davis, *Chairman* . . . . Washington, D. C.
C. R. Buller . . . . Pleasant Mount, Pa.
Thaddeus Surber . . . . St. Paul, Minn.
John D. Babcock . . . . Victoria, B. C.
W. E. Albert . . . . Des Moines, Iowa
Guy Amsler . . . . Little Rock, Ark.
Charles R. Pollock . . . . Seattle, Wash.

Committee on Foreign Relations

Henry O'Malley, *Chairman* . . . . Washington, D. C.
A. G. Huntsman . . . . Toronto, Canada
Wilbert A. Clemens . . . . Nanaimo, B. C.
Carl L. Hubbs . . . . Ann Arbor, Mich.
Frederic C. Walcott . . . . Norfolk, Conn.

Committee on Relations with Foreign and State Governments

Lewis Radcliffe, *Chairman* . . . . Washington, D. C.
J. W. Titcomb . . . . Hartford, Conn.
B. O. Webster . . . . Madison, Wis.
H. B. Ward . . . . Urbana, Ill.
Geo. W. McCullough . . . . St. Paul, Minn.
John Van Oosten . . . . Ann Arbor, Mich.

Committee on Publications

David L. Belding . . . . Boston, Mass.
John W. Titcomb . . . . Hartford, Conn.
Geo. C. Embody . . . . Ithaca, N. Y.
H. S. Davis . . . . Washington, D. C.

On motion of Mr. Wicks, seconded by Mr. Rodd, the report was unanimously adopted, and the secretary was instructed to cast one ballot for the list as read.

Retiring President Belding: In extending our congratulations and best wishes to our newly elected president, I think it is appropriate that we should pay him on this occasion a special tribute. Therefore I shall ask Dr. Emmeline Moore to escort Mr. LeCompte to the chair.

PRESIDENT-ELECT LECOMPTE: I thank Dr. Belding very much for his kind remarks, and I wish to congratulate him on the success of the Toronto meeting. I desire to thank the members of the Society for the great honor they have conferred upon me. I am not a scientist, nor am I a fish culturist, but I have always had a great interest in matters affecting the conservation of our game and fish supplies. I shall do all I can to further the interests of the Society and to make the meeting at Hot Springs, Arkansas, in 1931, a success. I thank you again for this honor, which I appreciate more than I can say, and I hope to see you all at Hot Springs in 1931.

Whereupon the Sixtieth Annual Meeting of the American Fisheries Society was adjourned to meet in Hot Springs, Arkansas, in 1931.

IN MEMORIAM

Carlos Avery

L. F. Ayson

C. C. Bolton

Edward H. Floyd-Jones

F. S. Landstreet

Eugene D. McCarthy

Ben F. Moore, Jr.

G. H. Thomson

PART II

PAPERS AND DISCUSSIONS

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THE PRESENT STATUS OF FISH CULTURE IN THE PROVINCE OF ONTARIO

H. H. MacKay

Biologist and Director, Fish Culture Branch, Department of Game and Fisheries, Ontario

Consideration of the geographical extent and geological features of the Province of Ontario will give some idea of the working-field pertaining to problems respecting the propagation and preservation of fish and the magnitude of the task confronting the Fish Culture Branch of the Ontario Department of Game and Fisheries.

The Province extends from Quebec on the east to the Great Lakes and Manitoba on the west, and from the Great Lakes on the south to James' Bay on the north, comprising on the whole an area of 407,262 square miles. The water area over which the Department has jurisdiction from the fisheries' standpoint approximates 80,000 square miles, which is accounted for in part by the Canadian portion of the Great Lakes, 38,000 square miles, and in addition by a vast assemblage of inland waters, the majority of which are confined to the Pre-Cambrian or igneous rock formation of Northern Ontario. The depressions in these rocks left by the glacial period lodge an almost continuously connected series of overflow basins ranging in size from mere ponds to considerably large lakes, for example, Lake Nipigon (1,530 square miles of water) and Lake Nipissing (330 square miles).

In these waters, granting certain regional peculiarities, there is a wide natural distribution of game-fish, such as speckled trout, bass and maskinonge, and of semi-game-fish, such as pike, pickerel and lake trout, and with the exception of a few inland lakes where commercial fishing is allowed the majority of Provincial waters are reserved for game-fishing mainly on account of their attractiveness for lovers of healthful recreation and the appreciation of these lakes by native and summer-resident sportsmen. It is a fortunate circumstance that the principle of reserving inland lakes for game-fishing has been supported by both Dominion and Provincial Parliaments throughout the years.

The manner and extent of the use of the Canadian portion of the Great Lakes for marketable fish will always play a significant part in the activities of the Fish Culture Branch, but the major problem with which this paper is entitled to deal is:

"What is being done within the province of fish culture to maintain in a practical way the game-fishing areas in the Province of Ontario, in view of the increasing numbers of tourist fishermen who spent in angling licenses in 1929, a sum of $214,470.25."

To the Fish Culture Branch is entrusted the study of Provincial waters from the standpoint of their suitability and other allied problems relating to the fisheries. To the Fish Culture Branch there

is also entrusted the direction and supervision of the work of hatcheries. The capital investment in these activities amounts to approximately half a million dollars, and the appropriation for the fiscal year 1929–30 amounted to $272,500.

The biological field work is done during the summer months by qualified students, graduate students and professors of our three major universities, namely, Toronto, Queen's and Western, and at the present time eighteen university men are engaged in the service as seasonal field assistants. In addition, one technical assistant and one assistant biologist are employed in the laboratory of the Department. It should be pointed out in this connection that the Department of Biology, University of Toronto, has a fisheries' laboratory known as the Ontario Fisheries' Research Laboratory, in which special training is given in fishery problems. This is a very fortunate circumstance.

Scientific data on all our important lakes and streams must be collected before fish husbandry can be a success, and since its inception in 1925 the biological component of the Ontario Department of Game and Fisheries has entered upon a systematic survey of the physical, chemical and biological conditions of the waters throughout the Province to determine in advance of stocking the suitability of the waters for the growth and reproduction of fish, in order to be in a position to formulate a more satisfactory, consistent and intelligent basis for re-stocking.

In these preliminary surveys standardized methods of procedure based on known criteria applicable to such investigations are consistently followed, in order to allow for comparisons among the different waters studied, particularly as regards physical, chemical and biological conditions. The data collected are carefully compiled, and statistics embodying the plantings in each individual lake or stream are kept, so that we may be in a position to compare the results of the stocking policy with fishing conditions from time to time. All the waters under the Department's jurisdiction are listed and a permanent policy as regards species is established.

Up to the present time, the Branch has made an intensive and comprehensive survey of Lake Simcoe and preliminary surveys on at least seventeen hundred waters. At the present time, a compilation of these studies is under way for publication in the near future. In addition, the method of taking watersheds as a unit of study has begun, and will be more generally adopted when a knowledge of the general situation has been obtained.

Apart from the general character of the water supply, there is nothing more important than diet in the culture of fish, and in order to study the nutritional requirements of trout under properly controlled laboratory experiments, an experimental laboratory was established at the Mount Pleasant Fish Hatchery in 1929. The initial work in this connection was done by Professor J. D. Detwiler,

of Western University, London, Ontario, and during the current year Dr. I. L. Chaikoff, of the Department of Physiology, University of Toronto, and now of the Department of Physiology, University of California, and Mr. R. D. H. Heard, of the Department of Biochemistry, University of Toronto, in collaboration with Professor Detwiler and the writer, continued the problem and the results obtained will be presented to this Society by Professor Detwiler and Mr. Heard.

Our hatchery policy is a progressive one and has grown as a result of a need to replenish lakes and streams in order to supplement the work of nature in maintaining good fishing. It is not difficult to conceive of so many anglers on a body of water that natural production alone could not support good fishing. Since restriction of the number of anglers is impossible, re-stocking and restrictions in size limit, bag limit and season are the only possible solvents, and it is believed that, if artificial propagation is carried out along practical lines, properly guided from the scientific standpoint with due regard to conservation, dangers of depletion should be minimized.

In 1926 the Province had six hatcheries devoted to the propagation of both game and commercial fish and in 1926 nine additional hatcheries located in the Province under the control of the Federal or Dominion Government and used exclusively for the propagation of commercial fish were taken over. Since then, to some extent these hatcheries have been used for the propagation of game-fish, and it should be noted that Provincial hatcheries, under Provincial jurisdiction, were the first in Ontario to go into the propagation of game-fish extensively. The original object of these Provincial hatcheries was, in the main, the culture of game-fish.

At present, the Department's holdings include sixteen hatcheries, four rearing stations, and two large ponds used in the propagation of small-mouthed black bass in addition to the bass ponds at the Mount Pleasant Hatchery. The number of men employed in these hatcheries and rearing stations at the present time is fifty-four.

The names of the hatcheries, their locations and the species propagated are as follows:

Hatchery	*District*	*Species Propagated*
Kenora Hatchery	Kenora	Lake Trout, Pickerel, Whitefish.
Fort Frances Hatchery	Rainy River	Pickerel, Whitefish.
Port Arthur Hatchery (2)	Thunder Bay	Speckled Trout, Lake Trout, Pickerel, Whitefish.
Sault Ste. Marie Hatchery	Algoma	Speckled Trout, Lake Trout, Pickerel, Whitefish.
Coldwater Creek Rearing Station, Sault Ste. Marie	Algoma	Speckled Trout, Rainbow Trout. (Under construction for use in 1931.)

Hatchery	*District*	*Species Propagated*
Pembroke Rearing Station, Pembroke	Renfrew	Speckled Trout.
Belleville Hatchery	Hastings	Lake Trout, Pickerel, Whitefish, Herring.
Codrington Rearing Station, Codrington	Northumberland	Speckled Trout.
Glenora Hatchery	Prince Edward	Speckled Trout, Lake Trout, Pickerel, Whitefish, Herring
Lake on the Mountain (Glenora Hatchery)	Prince Edward	Small-mouthed Black Bass.
Mount Pleasant Hatchery	Brant	Speckled Trout, Brown Trout, Small-mouthed Black Bass.
Normandale Trout Ponds and Hatchery (1)	Norfolk	Speckled Trout, Rainbow Trout.
Normandale Hatchery (2)	Norfolk	Rainbow Trout, Whitefish, Herring.
Gibson's Creek Rearing Station	Norfolk	Speckled Trout.
Ingersoll Bass Rearing Pond	Oxford	Small-mouthed Black Bass.
Kingsville Hatchery	Essex	Whitefish, Herring.
Sarnia Hatchery	Lambton	Whitefish, Herring.
Southampton Hatchery	Bruce	Speckled Trout, Lake Trout.
Wiarton Hatchery	Bruce	Speckled Trout, Lake Trout.
Collingwood Hatchery	Simcoe	Pickerel, Whitefish, Herring.

The development of trout rearing stations is the outcome of a great and insistent demand for larger fish, and in the more populated districts where waters are more heavily fished the consistent introduction of large fish appears to be the only practical means of maintaining good fishing. A glance at Table II* shows that the general trend in the culture of trout and bass is in this direction, but it should be noted that there is not yet sufficient scientific evidence of a quantitative nature on the survival of deposited fry to discredit their introduction in suitable small tributary streams.

The establishment of District Rearing Stations is, we believe, a step in the right direction, for two reasons at least:

1. Transportation of fish over long distances is reduced. This is

*Table II was on exhibition at the meeting of the Society, but is not included here on account of its large size. The reader is referred to the Annual Report of the Department of Game and Fisheries, Ontario, for 1930 for the information in question.

Raceways for rearing trout fingerlings, Codrington, Northumberland County, Ontario.

important economically and also from the standpoint of the condition or health of the fish on arrival at their destination.

2. Fish are being reared in waters which flow over or through the same rock formation in which the fish will ultimately be introduced, providing the waters are suitable physically and biologically.

This method, though reasonable from the standpoint of transportation and protection of the fish from injury due to long hauls, and from sudden change in the reaction or chemical content of the water as opposed to that in which the fish were reared, may not be of any significance as regards the possibilities of the fish to survive in waters differing widely in chemical composition as shown in a comparison in Table I, of a number of waters supplying hatcheries located in various types of geological rock formations.

The mineral analyses were made by Mr. R. D. H. Heard of the Department of Biochemistry, University of Toronto, who acted as seasonal investigator in the Department of Game and Fisheries during the summer season of 1930. The analyses indicate:

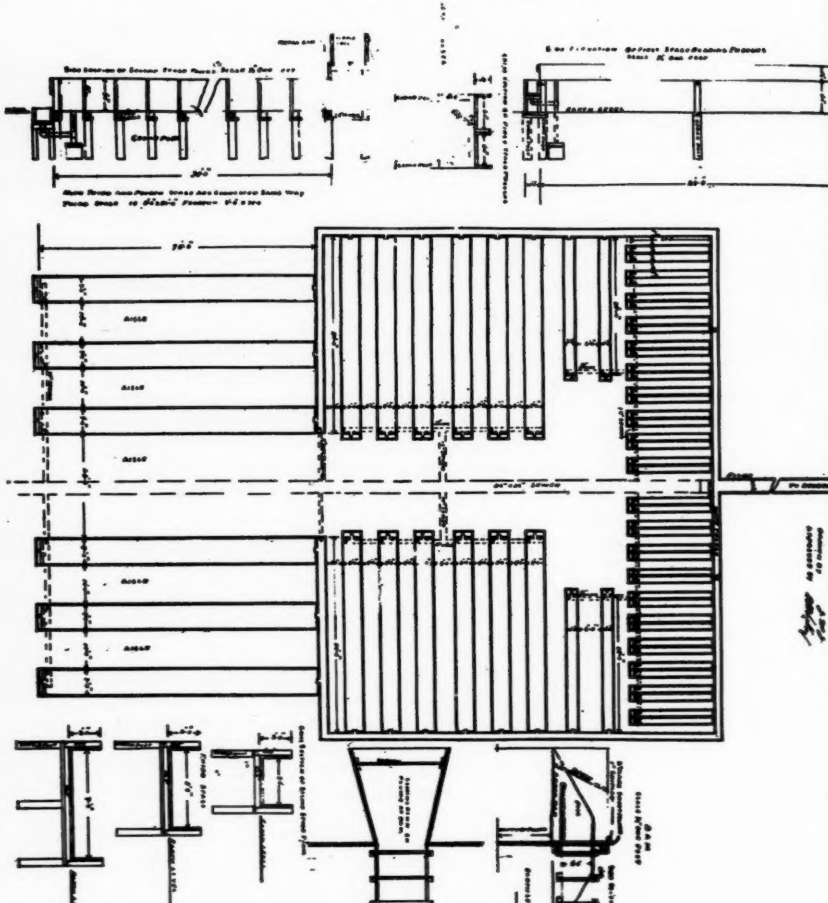
1. That sedimentary rocks contain a higher mineral content than igneous rocks; Mount Pleasant waters being the richest on account of the fact that the artesian wells, from which a certain amount of the water supply is obtained, flow through rocks heavily impregnated with calcium and magnesium.

2. The water supplies are practically free from albuminoid substances and are, therefore, free from pollution.

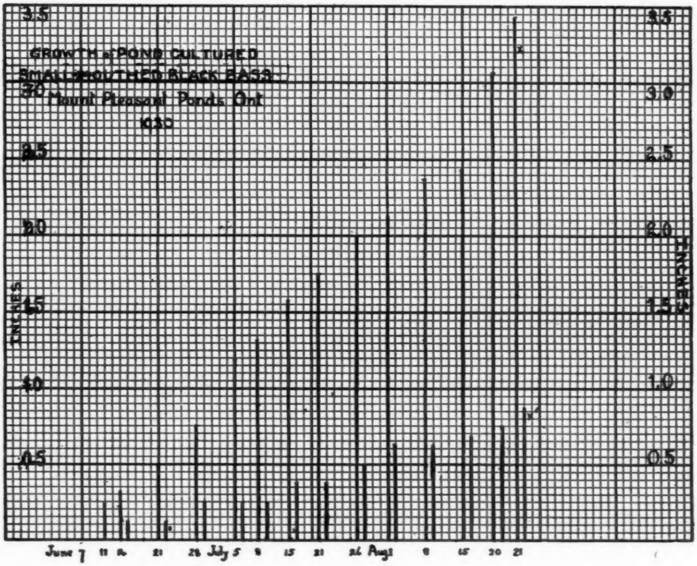
3. Although there is a very great difference in the chemical content of the water, speckled trout are able to endure any of these conditions and thrive satisfactorily, but the actual production-ratio of the various waters has not been worked out.

The process of carrying trout through the complete cycle from the egg to the adult stage is possible at the Normandale Trout Ponds, and is a principle which has received the support of many leading fish culturists. From acclimatized and domesticated trout at the latter hatchery the Department obtains the largest proportion of its trout egg supply, and plans to incorporate this same method in the new District Rearing Stations whenever and wherever practicable.

The accompanying plan of a trout rearing station illustrates the general principles covering the construction of those in present operation at Pembroke, in Renfrew county, and at Codrington in Northumberland county. The raceways are constructed so as to take care of a graded stock, fry being retained in the smaller raceways until they are feeding well, after which they are transferred to larger raceways. This structure is basic to general hatchery principles; the small raceways simulating the running feeders, and streams in which trout live in a state of nature. The raceways and rearing tanks in general use range in size from 2 feet to 10 feet in width and from 20 feet to 100 feet in length. Raceways for fingerlings in general are not over 5 feet in width or 75 feet in length. The raceways are of



Plan of the upper part of a trout-rearing station at Sault Ste. Marie, Ontario.



durable wood construction and the bottom is covered with sand or gravel. When the water supply warrants, raceways are separately fed and separately drained, and in all cases at our new rearing stations provision is made for a fresh supply of water to those raceways where water is used more than once. The bottoms of the raceways are sloped only slightly, and an effort is made to have the water in the lower end not more than twelve inches or thereabouts. We have found that this condition allows for a more or less equal distribution of the fish over the bottom; a condition which most fish culturists aim to obtain in order to give the fish a more equal opportunity.

Just a word about the culture of bass. After many years of patient toil and disappointing results, some success appears to be on the horizon, and this success is due in the main to making provision for the rearing of bass fry in rearing ponds entirely separate from the breeding ponds. Our results show conclusively that if we desire to rear bass by the pond method, it is useless to endeavour to try to do so by leaving the bass in large ponds with adults.

The food supply of the bass is of major importance, and since they will not take artificial food the natural food in the ponds must be increased by a suitable fertilizer. Horse manure and sheep manure were used this year with good results.

Good breeders are also of great significance. This year the bass in one pond were from domesticated stock, but there was nothing to show that the yield from domesticated stock was superior to that obtained from wild bass introduced to the second breeding pond used; in fact, the reverse condition appears more evident from direct observations.

Control of temperature by closing off the water on dull days and cool nights has done much to improve results in hatching.

Provision has been made for a suitable rearing pond for bass located near Ingersoll, Ontario. The pond covers an area of, approximately, twelve acres, and is so constructed that it may be satisfactorily drained. After this construction was effected, this summer, the margin of the pond was fertilized with horse manure; suitable aquatic plants were introduced, and also a quantity of adult golden shiners. Since this work on the pond was not completed early enough, it is impossible to look for results this year. However, as an initial test, a small quantity of small-mouthed black bass fry were introduced, and the samples of bass fingerlings taken from the pond in question and exhibited at the Society speak for themselves. There is absolutely no doubt regarding the possibilities of this pond to produce food for bass; this is apparent not only from the excellent rate of growth of the bass, but also from the excellent production of plankton crustacea, and golden shiners.

The rate of growth in inches of pond-cultured, small-mouthed bass at Mount Pleasant for 1930 is given in the accompanying graph. The August 21 figures indicate the size of bass from the Ingersoll Pond. These were originally fry which were transferred to the Ingersoll Rearing Pond from the Mount Pleasant stock.

During the present year systematic observations were made on the limnobiological features of all the Mount Pleasant ponds and collections of bass for stomach analyses were made. When this material is examined and the results correlated, we should be in a position to state more accurately what our ponds will produce per acre. One difficulty we have had during the daphnia-feeding stage is the prolongation of the asexual or parthenogenetic cycle of these crustaceans, or the prevention of winter-egg formation.

The chart* on exhibition gives a detailed classification of the distribution of fish during 1928 and 1929–30, which is more or less self-explanatory. It should be noted, however, that the distribution is by no means completed for the fiscal year as regards trout and bass. Large trout and bass fingerlings have not yet been distributed.

This then is a brief of some of the activities of the Fish Culture Branch directed at maintaining one of Ontario's chief assets, namely, its fisheries, and in conclusion it should be added that the recent report of the Ontario Government Game and Fish Committee

*Refer to the Twenty-Fourth Annual Report of the Department of Game and Fisheries, Ontario, for this information.

TABLE I. ONTARIO DEPARTMENT OF GAME AND FISHERIES
Chemical Analyses of Provincial Waters

Waters	Normandale			Mt. Pleasant Hatchery			Sault Ste. Marie		Codrington	Pembroke	Fort William
	Trout Ponds	Gibson's Creek	Hatchery	Stream	Well No. 1	Mixed	Hatchery	Cold-water Creek Rearing Station	Marsh Creek Rearing Station	Rearing Station	Spring Creek Rearing Station
Constituents	**Mineral Analysis**										
Total Solids 150° C	152	140	153	290	2125	1105	97	90	243	45	188
Hardness as Ca CO	119.5	102.9	121.9	229.7	1619	842	30.8	10.0	243	20.7	167.4
Nitrogen—Free Ammonia	0.04	0.06	0.05	0.05	Trace	0.1	0.046	0.02	0.05	0.033	0.045
Nitrogen—Albuminoid	0.05	Nil	Nil	Trace	Trace	0.005	Nil	Nil	Nil	Nil	Nil
Silica $Si\ O_2$	Trace	Nil	Trace	Trace	Nil	Trace	Nil	Nil	16.8	36.8	Trace
Iron $Fe_2\ O_3$	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	16.8	Nil
Calcium—CaO	58.0	55.6	58.8	88.4	755.5	384	17.2	5.6	106.4	Nil	59.2
Calcium—CaO percentage of total solids	38.1	39.6	38.4	30.4	35.8	34.7	17.7	6.23	43.8	Nil	31.5
Magnesium—MgO	6.5	1.2	6.8	28.24	108.2	63.5	Nil	Nil	21.28	Trace	24.8
Magnesium—MgO percentage of total solids	4.3	0.83	4.4	9.66	5.09	5.75	Nil	Nil	8.77	Trace	13.2
Inorganic Phosphates (P_2O_5)	2.61	2.83	2.12	3.37	4.70	4.22	1.06	3.14	3.94	3.89	2.82
pH (Electrometric) when received	7.7	7.6	7.7	8.23	7.93	8.06	7.19	6.34	8.19	7.18	8.13
Geology—*Period Formation*	Middle Devonian Delaware			Upper Silurian Camillas			Precambrian Timiskamian		Ordovician Trenton	Precambrian Algoman	undifferentiated
Geology—Nature of Deposition	Limestone			Shale, Dolomite, Gypsum and Salt			Igneous		Limestone	Igneous	
	Field Analysis										
Date of Analysis, 1930	June 16	Aug. 23	Aug. 23	Aug. 23	Aug. 23	Aug. 23	Aug. 7	Aug. 8	Aug. 1	Aug. 5	Aug. 12
Temperature, °F.	59.5–70.0	52	64	54	50	52	66	48	53	59.5	52
pH Colorimetric	7.4– 7.9	7.6	7.65	7.8	7.1	7.35	7.7	6.8	7.6	7.1	7.5
Dissolved O_2 c.c. per litre	4.8– 7.3	6.2	6.0	6.2	1.9	4.7	6.5	6.4	6.8	6.3	5.65
Free CO_2	0.5– 4.5	3.0	4.3	4.0	14.0	10.0	0.6	1.9	3.3	1.8	3.5
Methyl Orange Alkalinity—as $CaCO_3$	65–74	132.6	136	203.4	162.8	184.0	51	24	212	25	185
Phenolphthalein Alkalinity—as $CaCO_3$	0	0	0	0	0	0	0	0	0	0	0
Temperature Range °F. June-August	52–70	52	56–80	50–64	....	....	48–67	45–55	53	52–59.5	52
Flow—Gal. per min.	100–500	100–500	800	500	200	700	175	1347	673	336	12,220

appointed to inquire into certain phases of the game-fish situation in Ontario, and to recommend measures of improvement, is a specific and most valuable contribution to the Department's efforts in this direction.

Discussion

Mr. MacKay: The reason for the establishment of rearing ponds in Ontario is found in its vast expanse and the necessity of reducing the cost of transportation. We are attempting, therefore, to establish a rearing section in each district of the province. There are striking differences in the amount of mineral substances in the various waters. For instance, at Pembroke which is situated in the pre-Cambrian section of the province of Ontario, where igneous or metamorphic rocks abound, the total solids are forty-five parts per million as compared with two thousand at the Mount Pleasant Hatchery. Furthermore there is a difference in the hydrogen-ion concentration in water which comes from the igneous rock formation and that which comes from the sedimentary rocks.

Mr. Titcomb (Connecticut): I should like to inquire of Dr. MacKay as to the productive capacity of the different water supplies per volume of flow. Can you not raise more trout in a certain volume of flow in some hatcheries than you can in others?

Mr. MacKay: Yes, the volume of flow in our different hatcheries varies appreciably from one hundred to eight hundred gallons per minute. Provided other conditions are equal, we can raise more trout at a hatchery where we have two hundred gallons per minute than we can at a hatchery with one hundred.

Mr. Titcomb: You have more lime in some hatchery waters than in others?

Mr. MacKay: At Pembroke we are rearing speckled trout to the length of four and a half inches, and there is no appreciable calcium in that water.

Mr. Titcomb: You have the same amount of oxygen in each of these waters?

Mr. MacKay: There is a difference in the amount of oxygen. The amount of dissolved oxygen depends largely on the temperature of the water. At Normandale it ranges from 4.8 to 7.3 cubic centimeters per litre, and at Gibson's Creek, from 6.0 to 6.2 at its source, but in a short distance the flow is broken by series of rapids and falls so that it immediately becomes saturated with oxygen.

Mr. Titcomb: From your tables you have a minimum amount of oxygen at Mount Pleasant—$1\frac{9}{10}$ cubic centimeters per litre. Can you carry as many trout per same sized pool as you would in a hatchery where you had $6\frac{2}{10}$ cubic centimeters of oxygen?

Mr. MacKay: No.

Mr. Titcomb: In other words, the productive capacity of your hatcheries varies with your water supply?

Mr. MacKay: Absolutely.

Dr. Emmeline Moore: The analysis which you have presented is a most significant one for fish culturists. I should like to ask whether the placing of your field stations and hatcheries has been based upon such a careful analysis, or whether by trial and error you have found out whether or not the water is suitable.

Mr. MacKay: Before establishing a rearing station we examine the site and water. For a number of years we have wanted to establish rearing stations, but it is difficult to find a water supply that meets our requirements.

Mr. Titcomb: Are you sure that this type of analysis will determine the practicability of the site for the rearing of a suitable number of trout.

Mr. MacKay: I believe these analyses are important, but in view of the fact that we can rear trout successfully in any of these waters I am unwilling to say that they are of major importance. Nevertheless I consider that these analyses are important in regards to the proportion of fish that we can produce at these hatcheries, because they are directly concerned with nutritional requirements.

Mr. Rowe (Maine): What is the iron content of these waters?

Mr. MacKay: So far as we have been able to determine at Normandale, Mount Pleasant, Sault Ste. Marie and Fort William, the iron content is negligible, whereas at Pembroke the water has a high iron content.

Mr. Titcomb: Would you consider oxygen the most important factor in the analysis?

Mr. MacKay: In any water supply for rearing fish I would consider the oxygen supply and the temperature most important.

Mr. Rowe: In my experience with different hatchery waters I have noticed that in waters with a high iron content the fish did not do nearly as well and that eggs do not develop as well as in waters with a low iron content.

Mr. MacKay: I believe you are correct. At Mount Pleasant where we were bothered with a high iron content we ran the water through a trough in order to precipitate the iron by oxidization.

Mr. Thaddeus Surber (Minnesota): Do you find any trouble with fingerling fish transportation from one region to another when reared in a large flow of water?

Mr. MacKay: That is an important point and it is one of the reasons that we are developing district stations. Formerly we used to carry our fish a tremendous distance across the province, whereas now from district rearing stations we plant fish that have been acclimatized in water of the same region. Nevertheless we have planted trout successfully from one region to another. In fish reared in an unlimited flow we have noted that the growth was almost double that of another hatchery with less flow of similar water. We find that the fish which have had an abundance of water and a corresponding abundance of oxygen are very difficult to transport successfully. Therefore I believe that we can overdo the matter of providing our trout with a superabundance of oxygen.

Mr. Fred A. Westerman (Michigan): Have you made any competitive tests with a view to determining the efficiency of sand as compared with gravel bottom in the troughs?

Mr. MacKay: No, but we favor the gravel bottom.

Mr. Westerman: I question whether it has any advantage over the ordinary wood trough.

Mr. Charles E. Wheeler (Connecticut): The majority of the trout produced in hatcheries are dark colored on the surface and have a white-meated interior. The thought has occurred to me that inasmuch as a return to natural conditions in oyster culture has produced success, a return to natural conditions in respect to rearing trout, even though we have to manufacture the natural environment, may tend to produce a better color in the trout and thus result in the production of a more handsome fish, with that beautiful orange pink color of the meat which we so much admire. I have suggested this idea to one or two fish culturists; one was very much interested in the

suggestion; another thought there was nothing whatever in it. In Connecticut we have been carrying on extensive experiments in the matter of foods. If we could grind up certain species of waste salt water fish and crustaceans in the raw state and keep them fresh until they could be fed to trout, I feel sure that they would supply a substitute for fresh water shrimp.

Mr. James A. Laird (Long Island): I have been doing for years the very thing that you suggest, and I still have black fish. I have been feeding skate, dog-fish and all kinds of salt water products, and I still have black fish and white instead of pink meat.

THIRTY-SIX YEARS' EXPERIENCE IN FISH CULTURE

A. W. McLEOD

Supervisor of Hatcheries, Fish Culture Branch, Department of Game and Fisheries, Ontario

Fish culture in Ontario was first taken up privately by the late Samuel Wilmot in 1866 at Newcastle. In 1868 the first operations were carried on by the Department of Marine and Fisheries of the Federal Government. At that time Mr. Wilmot was Superintendent of Fish Culture and continued in that capacity until a short time before his death in 1897, at which time all fisheries and fish cultural developments were carried on by the Federal Government at Ottawa.

The greater number of hatchery managers in the early days of fish culture in Canada were men who were trained under Mr. Wilmot in Newcastle. Many of these men spent their whole lives in the service and were highly competent in the propagation of fish. The work was entirely with the commercial varieties,—salmon, whitefish, lake trout, yellow pickerel. The eggs were taken by the commercial fishermen, and we would now consider the equipment used in the early days as somewhat crude. Samples of the equipment used for experimental purposes were for a long time stored at Newcastle, and it would be interesting if they could be had now to show the different improvements which have taken place.

From 1893 to 1919 my work was principally in the culture of the commercial varieties of fish, but each year we always hatched a small quantity of speckled trout, and from 1914 we hatched and reared black bass with success considering the pond space with which we had to work.

The principal egg collection was carried on with the aid of the commercial fishermen on the Great Lakes. I have operated in almost every important fishing station from the eastern end of Lake Ontario to the head of Lake Superior, and in my association with most of the fishermen in this work, I have received in most cases the best possible co-operation. I have been associated at different times with the fish culturists in the United States, including such outstanding men as Mr. J. P. Snyder of Cape Vincent; Mr. Philip Hartman of Erie, Mr. G. Buller of Pleasant Mount, Mr. A. Buller of Corry, Pa.; Mr. Miller of the Ohio State Hatchery and Mr. Downing of the Put-in-Bay Federal Hatchery. I have had the pleasant experience of visiting a number of hatcheries in the States of Massachusetts, New York, Pennsylvania, Ohio, Michigan, and Wisconsin. Meeting the various hatchery officers and discussing problems with them from time to time have proved interesting as well as instructive.

There is one outstanding fish culturist I wish to mention, and that is the late James Nevin of Madison, Wisconsin. Mr. Nevin started his work in the Newcastle Hatchery under the late Samuel Wilmot. He was appointed manager of a hatchery at Sandwich, Ontario, and

resigned from the Canadian service to accept the position of Superintendent of Fisheries for the State of Wisconsin, which position he held for a number of years. Together with Mr. B. O. Webster I had the pleasure of inspecting a number of the hatcheries erected by Mr. Nevin. I have also associated with a number of fish culturists in Ontario, such men as the late A. B. Wilmot; the late Charles Wilmot; the late William Parker; the late John Walker; Mr. A. J. McNab, who was employed for a number of years in Duluth Hatchery; Mr. F. H. Cunningham; Mr. A. Finlayson; Mr. Stanford Walker; Mr. J. A. Rodd, the present Director of Fish Culture for the Federal Government and numerous others in the service.

I was transferred in 1919 from the Federal Department of Marine and Fisheries to the Department of Game and Fisheries for Ontario. At that time there were only the following hatcheries in operation,—a bass and speckled trout hatchery at Mount Pleasant, which had been operating for eight seasons; one trout and whitefish hatchery at Normandale, operated for two seasons; and another hatchery at Port Arthur, operated one season. Since 1920 the Department has paid particular attention to the game-fish propagation.

At the Normandale and the Mount Pleasant Hatcheries, we now have a stock of parent speckled trout, rainbow trout, and brown trout, from which we can secure sufficient eggs of each species to supply our hatcheries, rearing tanks and ponds. We now have sixteen hatcheries in operation, four rearing stations for trout, where we can rear the different species of trout to the age of six and eight months, and even produce yearlings.

The rearing of trout is a relatively easy matter and has long since passed the experimental stage. The all important matter is the securing of a satisfactory supply of pure uncontaminated water under perfect control.

In rearing bass in large numbers they must have a free, wide range and a natural food supply, as they will not feed successfully on artificial food the same as trout. Bass can be raised to three and four inch fingerlings. To give the fish the necessary range and food, much larger rearing plants will have to be developed and also a plant will have to be developed to rear the necessary food to feed the bass. From the fry to the four-inch fingerling stage it requires large ponds so constructed that each pond can be drained and the bass removed with the least handling possible. The ponds should be fertilized and prepared for the following spring, and the water supply so controlled that no enemy fish would be permitted in ponds where the young bass were being reared. The parent bass should be placed in small breeding ponds until the fry are hatched and then the fry should be removed to the larger rearing ponds where they would be free from enemy fish or their parents. The success would then depend on the supply of live food in the ponds, and the extent of the range since bass are cannibalistic and will devour each other if sufficient food is

not available. To build a plant large enough to give results necessary for anything near the demand would cost at least half a million dollars. The question is would the results obtained justify the expenditure. The same problems apply to rearing maskinonge and yellow pickerel (dore) beyond the fry stage.

I have inspected a number of bass hatcheries in the United States and while they are producing a number of young bass in proportion to the size of the ponds, in my opinion to get practical results much larger areas where the bass will have large range with natural food available in large quantities will be necessary to prevent cannibalism. The matter of bass and maskinonge culture, which in my opinion is a very important one, particularly to the Province of Ontario, is being developed and energetically studied by the Fish Culture Branch with which I am associated.

SOME PRINCIPLES OF BASS CULTURE

H. S. Davis

U. S. Bureau of Fisheries

For various reasons the propagation and rearing of bass has received much less attention than that of trout. This is no doubt largely due to the common impression that bass culture is relatively difficult and expensive and for that reason should only be undertaken as a last resort. However, I believe that this is an entirely mistaken idea and I can see no reason why fingerling bass cannot be produced at a reasonable cost. Owing to the large amount of pond area required the initial cost of a bass station is considerably greater than that of a trout station of the same productive capacity. On the other hand the upkeep of the bass station will be much less since the food bill, which is the most important item in the budget of the trout culturist, is reduced to relatively small proportions and there is a considerable saving in labor.

As everyone knows the principles involved in the production of bass are quite different from those which must be followed by the trout culturist. Although this fact is a perfectly obvious one I fear that fish culturists not infrequently allow themselves to be influenced—more or less unconsciously—by their earlier training at trout hatcheries to the detriment of their success as bass culturists. So accustomed have they become to a large flow of water through a pond that they forget that the continuous circulation of water is the last thing to be desired in a bass pond. In fact only sufficient water should be allowed to flow into a pond to replace that lost by evaporation and seepage. This means that a bass pond should be operated on the principle of a balanced aquarium. I do not intend to imply that in some instances a good production of bass may not be obtained in a pond through which there is a continuous flow of water but this is certainly an uneconomical way to operate a bass pond and in most instances it will be found that the production of fingerlings is in inverse proportion to the overflow.

Where the water supply is derived from springs and there is a continuous flow through the ponds it not infrequently happens that the temperature is too low for bass and the fish culturist wonders why his ponds are unproductive. There is little danger of a bass pond becoming overheated but temperatures below 70 F. are not conducive to the best results.

Another reason for preventing any overflow from a bass pond is based on the habits of the fry. When the fry first rise from the nest and begin to swim about in schools they tend to go with the current rather than to swim against it. They are, in fact, negatively rheotropic and undoubtedly large numbers of fry have been lost because this fact has not been generally realized. In most cases it is impracticable to use a screen at the outlet with a mesh fine enough to

prevent the small fry from passing through. Consequently, when there is a considerable overflow there is great danger that many of the fry may escape from the pond.

This habit of the bass fry was strikingly shown last spring in one of the sloughs on the Mississippi River. This slough was used as a spawning pond and before all the fry could be removed a sudden rise in the river caused the water to flow from this slough into an adjoining one. As a result thousands of young bass collected along the screen which had been placed across the connection between the sloughs. In fact this screen made a most effective trap for the capture of the fry. I have also been told of instances where entire schools of fry were observed to escape through a small hole in the bottom of a pond. Formerly I felt somewhat skeptical regarding the accuracy of such observations but now I am inclined to accept them at their face value.

Finally, we must consider the loss of valuable food material in the drainage water. We all know that the successful farmer takes every precaution to prevent the leaching of valuable fertilizing constituents from the soil and his example should be rigorously followed by the pond culturist. The principle in both cases is exactly the same. All food material carried away in solution or in suspension is a total loss so far as the pond is concerned. But in spite of all we can do there is always some loss through seepage and every fish removed from the pond means a still further decrease in the food reserve. True, the available food supply is receiving continual additions from the adjacent land and also from the soil on the bottom but the amount is far too small to compensate fully for the material carried away in the drainage water, removed in the form of fish or otherwise lost to the pond. Consequently, if we are to maintain the maximum production of fish from year to year we must either feed them or apply fertilizer which, of course, is simply an indirect method of producing the same result. Whether it is best to feed the fish directly or to rely chiefly or entirely on the application of fertilizers is a problem which each fish culturist must decide for himself. Unquestionably he must resort to one method or the other, or to a combination of the two, if he is to maintain a high productivity in his ponds.

Where an exceptionally high production is desired and the cost is a secondary consideration it will be best to resort to direct feeding, first with Daphnia or similar organisms and later with minnows. These should be raised in small ponds devoted solely to this purpose. However, I believe that in most instances it will be found more economical in the long run to produce the food in the bass ponds themselves rather than to rely chiefly on that produced in forage ponds. Undoubtedly it will be advisable to supplement this occasionally by the addition of food from outside sources but I believe that, as a general thing, we should strive to make the ponds self-sustaining. Of course, when ponds are heavily stocked with brood

fish it will be necessary to feed them regularly, but in rearing fingerlings this is by no means necessary.

It is generally agreed that the young of black bass at first subsist principally upon entomostraca and a little later when about an inch long begin to feed upon the smaller aquatic insects. As they increase in size larger insects appear in the food and shortly thereafter the young bass begin to feed upon small fish. After the fingerlings reach a length of about two inches they apparently subsist largely upon fish when these are available. This being the case, if we can provide the bass fry and small fingerlings with entomostraca and insects for a short time and follow these with a continuous supply of small fish they should make an uninterrupted growth throughout the summer.

Since entomostraca feed principally upon algae and small fragments of vegetable material plant growth in the ponds should be stimulated early in the season by maintaining as high a temperature as possible and by the application of fertilizers. Unless the ponds are heavily stocked with fry they should produce, under favorable conditions, sufficient entomostraca to satisfy the needs of the young bass until they are able to eat larger organisms. However, if more than 20,000 to 25,000 fry to the acre are to be held in a pond for any length of time it is advisable to add additional crustacea at frequent intervals.

So far we have no practicable method of materially increasing the supply of aquatic insects but ordinarily these organisms are sufficiently abundant to tide the young bass over the transition stage until they can subsist chiefly on forage fish with which the ponds should be liberally stocked. As in the case of entomostraca, unless the ponds are heavily stocked they can be made to produce sufficient forage fish to support the bass fingerlings. For this purpose the ponds should be stocked with brood minnows early in the season. These fish should spawn through the spring and summer months thus insuring a supply of small minnows for the bass throughout the season.

The use of nursery or rearing ponds for holding the young bass through the summer is believed to be advisable since the fry can be utilized to better advantage than by other methods. Where the young bass are reared in the same pond with the adults there is bound to be some competition for food which may result in cannibalism. The whole tendency in holding the young and adults together throughout the summer is to reduce the production of fingerlings. Some bass culturists remove the adults to holding ponds after the spawning season but we believe it is preferable to remove the fry to nursery ponds and allow the adults to remain where they spawned. The latter method provides complete control over the number of fry to be allowed in the ponds so they can be stocked at any desired intensity. Furthermore, it is possible to stock a pond with fish of the same age and size which, obviously, will tend to reduce the losses from cannibalism.

By the method just outlined, without resorting to direct feeding,

we have produced as high as 11,500 three-inch fingerlings to the acre. The average survival of young bass at the end of the season is from 35 to 40 per cent although we have in many instances obtained a considerably higher rate. In one instance it was 56 per cent.

Naturally this method of producing fingerlings will not result in such high yields as where more intensive methods are employed and direct feeding is practiced on a large scale. On the other hand the upkeep of the ponds costs very little since labor is reduced to a minimum and only a relatively small amount of fertilizer is required. Under favorable conditions ponds managed in this way should produce from 8,000 to 10,000 three-inch fingerlings per acre which is by no means a poor return on the capital invested.

Discussion

Dr. Davis: The conclusions given in that paper are based primarily on our experimental work with large-mouth bass at Fairport. My experience with small-mouthed bass at first hand has been quite limited but so far I have found no reason to believe that essentially the same methods cannot be used with both species.

For the past three seasons we have devoted one pond at Fairport to the propagation of small-mouthed bass with uniformly satisfactory results. No water is allowed to flow through the pond in spite of the fact that it is filled with muddy water from the Mississippi and the temperature often gets quite high. We have never had any trouble with the fish and last year, although the small-mouthed bass pond was operated as a combined brood and rearing pond, the production of 2 to 5 inch fingerlings was at the rate of 10,615 per acre.

For various reasons the propagation and rearing of bass has received much less attention than that of trout. Undoubtedly this is largely due to the common impression that bass culture is relatively a difficult and expensive proposition, and that therefore it should not be undertaken except as a last resort. I believe that this is an entirely mistaken idea, for I can see no reason why bass fingerlings cannot be produced possibly as cheap as or even cheaper than trout of the same age. It is true that the initial cost of the bass station is much greater than that of a trout station of the same productive capacity. On the other hand, the upkeep of a bass station is much less, largely due to the fact that the food bill, which is such an important item in the budget of a trout hatchery, is reduced to small proportions.

Mr. Thaddeus Surber: The members who were present at the Minneapolis meeting last year saw the Izaak Walton League bass pond at South Minneapolis. After the meeting we took from it in about a month something over 103,000 five-inch large-mouthed bass fingerlings. The pond has an acreage of approximately twenty acres, which would give about 5,000 fingerlings per acre. The pond is naturally fertilized since the decaying sod has produced an enormous quantity of entomostraca and insect larvae. No attempts to feed the fingerling bass artificially were made. The luxuriant algae which covered the entire pond provided shade and protection for the entomostraca and insect larvae, and protected the young bass from predatory birds. In other words, the pond was a self sustaining and self fertilizing unit under natural conditions.

Dr. Emmeline Moore: May I ask Dr. Davis if he finds it impractical in certain locations to keep the adult brood stock year after year in the same pond? In our bass hatcheries in New York State we do not keep the breeders in the ponds. They are taken by seining in the spring and after the spawning period are again released.

Dr. Davis: No; we find it practicable. We have some brood fish that have been kept in our ponds for at least six years and in some cases longer. In fact, they seem to be improving every year.

Dr. Emmeline Moore: You do not find that the bass tapeworm is affecting reproduction?

Dr. Davis: Only in one pond. We simply released these fish.

Mr. Brown (Arkansas): May I ask Dr. Davis to name the fertilizer which he has found best, and also what is the depth of his rearing ponds?

Dr. Davis: We are experimenting with different fertilizers, but I do not feel that we are in a position yet to say which is the best. The standard fertilizer we have been using with good results is a mixture of ordinary acid phosphate and dried sheep meal in equal proportions. We distribute it in small quantities along the margin of the pond, usually at intervals of about ten days to two weeks during the spring and the early part of the summer. The total amount we use varies from 500 to 1,000 pounds per acre for a season. We believe it is better to distribute the fertilizer at frequent intervals rather than at once, because there is less loss and we do not run into the danger of producing conditions which would be injurious to the fish.

As regards the depth of the pond, I consider five or six feet deep enough for ordinary purposes. In northern waters where you have winter fish in the pond you require a greater depth than in the South, but I see no advantage to be gained by using deep water.

SPAWNING HABITS OF THE SMALL-MOUTHED BLACK BASS IN ONTARIO WATERS

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INTRODUCTION

During the two years 1928 and 1929 an investigation of the life history of the small-mouthed black bass (*Micropterus dolomieu*) of Ontario was carried on in the waters of Georgian Bay and Lake Nipissing under the auspices of the Ontario Fisheries Research Laboratory of the University of Toronto. This summer, from May 30 to August 16, the investigation was continued in Lake Nipissing and adjacent small lakes.

PURPOSE

With the gradual disappearance of black bass from the waters of Ontario it has become apparent that further success in conservation can be obtained only when the complete life history of the black bass in its native habitat has been revealed. It is the object of this investigation to study such critical factors as spawning, food, and competition to obtain a complete life history of *M. dolomieu* from a purely biological viewpoint and at the same time to obtain information which might be useful for purposes of propagation and conservation. *This paper deals with some phases of spawning and early development of the black bass.*

GEOGRAPHICAL LOCATION OF INVESTIGATION

Georgian Bay is situated on the eastern side of Lake Huron. Lake Nipissing occurs about midway between the Ottawa River and Georgian Bay and its waters drain into the latter by means of the French River. The Goose Islands, where the spawning and development of *M. dolomieu* was studied this summer, are a group of rocky islands typical of the district, which extend for about a mile in length by half a mile in width and occur near the centre of the lake.

GEOGRAPHICAL DISTRIBUTION OF SMALL-MOUTHED BLACK BASS

The small-mouthed black bass occur in general throughout the numerous lakes and streams of southern Ontario. They are particularly abundant along the eastern shore of Lake Huron, including Georgian Bay and the North channel, in the French River, Lake Nipissing, Timagami district, Lake Erie, Lake St. Clair, and throughout the Trent Valley system from Georgian Bay to Lake Ontario. Bass have been introduced successfully into Lake of the Woods district. As far as is known, this marks the limit of their northerly distribution, none occurring in Ontario north of the 51st parallel of latitude.

Method of Investigation

Likely spawning locations were investigated by observation from shore or from a rowboat. Considerable difficulty was encountered in locating bass nests at a sufficiently early stage to observe spawning. When a nest was discovered records were made of oxygen and hydrogen-ion concentration, and Negretti and Zambra automatic thermometers were used to give accurate continuous records of the temperature variations of the water at the nest. Samples of eggs were taken by means of a large spoon attached to a stick and at a later stage fry were sucked up from the nest by means of a rubber tube. Round white-enameled dishes with a diameter of 13½ inches and a depth of 3⅝ inches were used to rear fry from the egg stage in order to make a comparative microscopic study of their development.

Chemistry of the Water

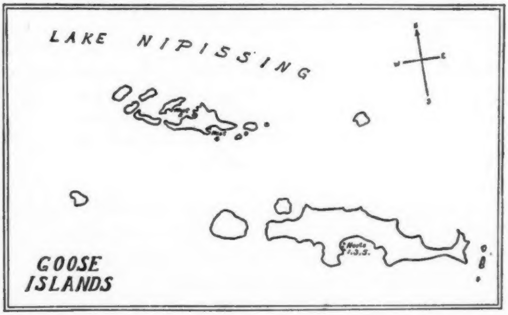
Records were kept this season of the oxygen and pH of the water over the nests and also in the hatching pans. At Nest 1 the oxygen varied from 5.7 to 6.4 c.c. with an average of 6.1 c.c. per litre. At Nest 4 on June 25 an oxygen determination as low as 5.2 c.c. per litre was obtained. The pH ranged from 6.9 to 7.2 with an average of 7.1. The oxygen in the pans varied from 4.1 to 6.9 c.c. with an average of 5.8. c.c. per litre while the pH showed a variation from 6.4 to 7.2, low oxygen being associated with an increased acidity. It would seem, therefore, that chemical conditions in the pans showed a fluctuation over a greater range than in the water over the nests but that, in using a fairly large shallow dish, sufficient oxygen was absorbed from the air to successfully sustain life.

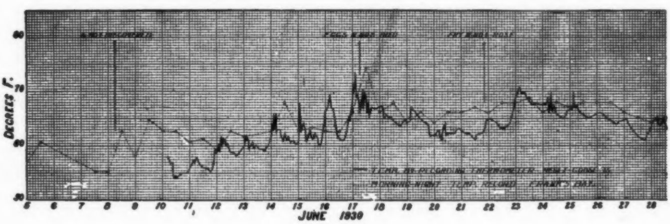
The Investigation

As is well known, the small-mouthed black bass spawn in fairly shallow water in rivers and streams or along the shores of lakes, preferably in locations which offer some protection from wind and wave action and from enemies. Reighard's work in 1905 at various hatcheries in the State of Michigan is still the most accurate scientific account of bass spawning. Beeman (1924) also published an excellent account of spawning and propagation. These authors explain very clearly how the male bass first sweeps out the nest, induces the female to deposit the eggs, and, finally, guards the fry until they are able to care for themselves. As yet, however, very little work has been done on the spawning of "wild" bass in their native habitat.

In the States to the South of Ontario spawning ordinarily takes place in May or June when the water has reached a temperature of 64°F. (Beeman, 1924.) In the more northerly latitudes in which Ontario is located the water does not usually attain this temperature until the month of June and accordingly spawning takes place at a later date than in the more southerly regions. At Lake Nipissing,

the ice has usually completely disappeared by May 10. (Graph No. 1, giving the morning and evening temperatures at Frank's Bay, Lake Nipissing, shows the general warming of the Lake during June, 1930.) Nest 1 was discovered at the Goose Islands on June 8 when the water had a temperature varying between 55° and 62°. Nests 2, 3, 4 and 5 were found on June 13, 15, 21 and 22 respectively. The accompanying map shows the location of these nests.





The nests studied this summer and those investigated in 1928 and 1929 were all located along rocky shores free from vegetation and usually on the eastern side of islands and in bays receiving protection from the prevailing westerly winds. When nests have occurred on the western shore they have been protected from wind and wave action by adjacent islands. The nests studied on Georgian Bay in 1928 were further protected from enemies on two or three sides by large sunken boulders or ledges of rock. Three of the five nests under observation this summer were beside or under dead fallen trees; the remaining two were on sloping rocky shores, unprotected from enemies by rocks or fallen trees. All had been made in water with a depth from 3 to 4 feet, the outer part of a nest consisting of small stones, which, in the case of those on Georgian Bay, were interspersed with aquatic vegetation about one inch in height.

In order to obtain a complete series of bass embryos and fry for a detailed study of their development, samples were taken from Nest 1 from June 11 to July 27 at suitable intervals. The eggs in this nest hatched June 10 and the fry rose on June 22, or 12 days after hatching. The scattering of the fry was a gradual process. On June 24 they were still grouped above the nest, the swarm extending for about one yard on either side. By July 1 they had scattered along the shore covering a distance of 70 yards. By July 4 this distance was increased to 315 yards, but, although extending over this distance, the fry always kept within 4 yards of shore. Even after the fry had scattered to this extent, they were still guarded by the male bass who patrolled up and down the shore chasing away pike which were the only fish noticed in the vicinity of the nest. The bass was seen for the last time on July 20. Hence in this case the young were guarded for at least 40 days after hatching.

Newly hatched fry were taken from the nest and reared in the hatching pan until they were at a stage comparable to that at which the fry rose from the nest. Specimens from this pan were taken and preserved at intervals until there were only two of the young bass left. These were placed in a square dish 3¾ inches by 4 inches by 1 inch, and fed copepods and Cladocera obtained in plankton hauls from the vicinity from June 22 to July 8. The water in this dish was not changed. Its temperature varied from 51.1° F. to 78.5° F., the oxygen from 5.4 to 8.5 c.c. per litre and the pH, at least from 6.0 to 8.0. Either the food supply was insufficient or the chemical conditions were unsuitable for the successful growth of the fry as on July 8 they were but 8 mm. in length as compared with a length of 16 mm. attained by those fry from the same nest in their natural habitat.

When Nest 3 was discovered on June 15 there were at least 2,000 eggs adhering to the stones and these seemed to have been deposited within 24 hours of the discovery of the nest. Samples of the eggs were taken and placed in a hatching pan. While these were being collected the spoon was attacked repeatedly by the guarding bass, sometimes causing the contents of the spoon to be upset and lost. This illustrates the care and fearlessness with which the black bass guards its young. The nest was guarded with rigorous care until the morning of June 18 or three days after its discovery. On this date the bass disappeared from the vicinity and on examining the nest, all the eggs were found to be dead and attacked by the fungus Saprolegnia. Graph No. 1 shows the variation in temperature of the water near this nest. It may be seen that on June 17 the water directly above the developing eggs reached a maximum temperature of 73.5° F. Eggs from this nest which were kept in the pan were in water with a temperature ranging from 64° to 68° F. for the greater part of June 17 and were not exposed to this high temperature until 3 P.M. when the water was changed. On June 18, the greater number

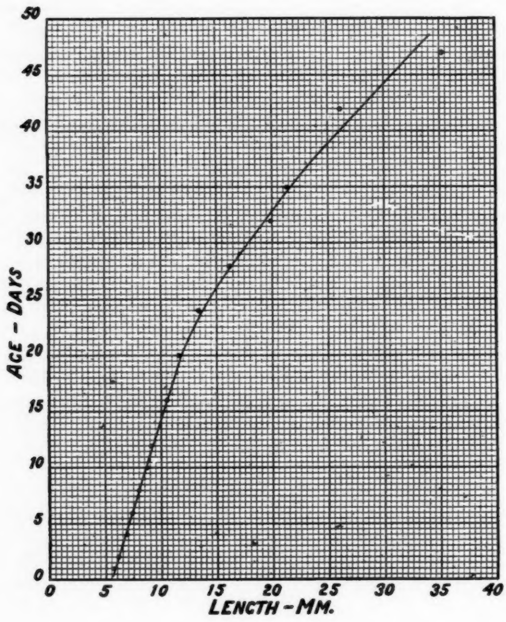
of eggs in the pan were dead also but a few survived and hatched that morning. Since this increase in temperature did not noticeably affect the fry of Nest 1 it would seem that bass eggs just before hatching are particularly susceptible to temperature change and cannot survive a rise from 61.0 to 73.5° F., this latter high temperature undoubtedly proving fatal.

The time of spawning, depending on the temperature of the water, varies with the geographical latitude, with the size of the body of water in which the nests occur, and with the earliness or lateness of the season. Table I gives a summary of information obtained on bass spawning for the last three years. It is noticeable that nest building had been completed in the case of Nest 1 (1930) when the water temperature still dropped as low as 55° F. The time between the deposition of the eggs and their subsequent hatching would seem to be from 2 to 3 days (Nest 1, Nest 3, 1930). In the case of Nest 1 (1930) the interval between hatching of the eggs and the rising of the fry was 12 days. Reighard and Beeman both state this interval as 14 days. The rate of development of the bass at this stage is in all likelihood a temperature reaction, the rate being proportional to the temperature. As there is now available a continuous temperature record covering this period between hatching and rising, it is possible to obtain the average temperature during the whole 12 days. This average temperature over the nest works out to be 62.0° F. with a variation between a minimum of 54.0° F. and a maximum of 73.5° F. From the table it may be seen that in the last three years the time of rising has sometimes extended into the open season for bass fishing which begins on July 1 in Ontario. The period between the rising and scattering of the fry is not definite. Usually it has been a gradual process extending over two or more days. The time of guarding by the male bass also varies and at Nest 1 (1930) lasted at least 28 days after the rising of the fry, that is, until July 20.

The Goose Islands have a shore line of approximately 4 miles in length. In 1930, 6 nests were found of which 4 nests were successful in producing fry, yielding possibly 2,000 each. At a very conservative estimate, Lake Nipissing and its islands and the French River as far west as the Chaudière Falls, have a similar rocky shore line of perhaps 150 linear miles. If this 150 miles were as productive as the 4 miles at the Goose Islands this would mean that as many as 300,000 bass fry were added to the waters of Lake Nipissing by natural propagation during 1930. The Goose Islands, however, are in a rather isolated location and only infrequently visited by the sport fishermen. With the bass fishing season opening on July 1 this total of 300,000 fry would undoubtedly be quickly reduced due to the possible capture of the guarding male from the nest with the resultant destruction of fry by predaceous fish.

The rate of growth of the fry of *M. dolomieu* after rising is very

rapid. Graph No. 2 shows the early development at Nest 1 (1930) as plotted from the data given in Table II. Bass eggs before hatching have an average diameter of about 2.5 mm. At the time of rising when 12 days old, the fry had an average length of 9.1 mm. and 48 days after hatching this had increased to an average length of 34.9 mm. The first part of the curve, extending over the period of yolk absorption, is practically a straight line. The latter part of the curve shows the more rapid development after rising when the fry are able to capture and assimilate plankton organisms.



Summary

1. Nests of "wild" small-mouthed black bass occur in locations which are sheltered from direct wind and wave action and are usually further protected from enemies by submerged rocks or fallen trees.

2. At a temperature varying between 54.0 and 73.5°F. with an average of 62.0°F. bass fry rose 12 days after hatching.

3. Large shallow pans of water absorb sufficient oxygen from the air to successfully hatch and rear bass fry as far as the stage at which they begin to feed.
4. Bass embryos, at a stage just previous to hatching, were killed by the temperature of the water rising as high as 73.5°F.
5. In 1928 and 1929 bass fry rose on a date that was within the open season for bass fishing.
6. In 1928, 1929 and 1930 nests were guarded by the male bass after the season for bass fishing opened, the guarding period in one case lasting until July 20.
7. It would appear that where conditions favour bass and there is a sufficient stock of mature fishes, natural propagation should be sufficient to maintain a stock if sufficient protection is given and there is no period of unfavorable cold or very warm seasons.

Acknowledgments

I wish to thank Professor W. J. K. Harkness for his kind supervision of the investigation and Professor B. A. Bensley and other members of the staff of the Department of Biology, University of Toronto, for valuable advice and assistance received.

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TABLE I GIVING TIMES AND TEMPERATURES RELATIVE TO SPAWNING OF *M. DOLOMIEU*

		Date of discovery of nest	Temp. of water (Deg. F.)	Date of hatching of fry	Date of rising of fry	Interval between hatching and rising (days)	Interval between rising and scattering (days)	Date male was last seen guarding nest	Time of guarding after rising of fry (days)
Georgian bay Go Home bay	Nest 1	June 24/28	68.7–11 a.m.		July 4/28		2	July 7/28	3
	Nest 3	June 27/28	69.1– 5 p.m.		July 4/28		2	July 4/28	0
	Nest 6	June 30/28	60.8– 3 p.m.		July 4/28		6	July 10/28	6
L. Nipissing French river		June 27/29	73.4– 2 p.m.		July 1/29		5	July 10/29	9(?)
L. Nipissing Goose Is.	Nest 1	June 8/30	55.4– 8 a.m.	June 10/20	June 22/30	12	7(?)	July 20/30	28
	Nest 4	June 21/30	66.0–11 a.m.		June 28/30		3	July 3/30	5
	Nest 5	June 22/30	64.9– 2 p.m.		June 23/30		7(?)	July 1(?)/30	7(?)

TABLE II GIVING DATA ON THE EARLY RATE OF GROWTH OF *M. DOLOMIEU*

Date	Age after hatching Days	Length mm.	Av. length mm.
June 11/30	1	5.6–5.9	5.7
12	2	6.0–6.2	6.1
14	4	6.8–7.1	6.9
16	6	7.2–7.5	7.4
18	8	7.8–8.2	8.0
20	10	8.5–9.0	8.7
22	12	8.7–9.4	9.1
26	16	10.0–10.9	10.5
30	20	11.0–12.0	11.6
July 4	24	13.0–14.0	13.4
8	28	14.8–17.0	16.2
12	32	17.5–21.7	19.8
15	35	20.3–22.8	21.3
22	42	21.7–29.5	26.1
27	47	32.2–36.6	35.2

Discussion

Mr. Titcomb: I should like to obtain further details about the automatic thermometer.

Prof. Harkness: It is the Negretti and Zambra recording thermometer.

Dr. Emmeline Moore: Is any special set-up necessary in order to make the thermometer continuously recording or did you just set it for low temperature?

Prof. Harkness: No, it runs on a drum; it is a continuous recording thermometer.

SPAWNING REACTIONS OF SMALL-MOUTHED BASS

M. C. James

U. S. Bureau of Fisheries

The paucity of information on the actual spawning reactions of the Centrarchid fishes appears to justify a detailed description of the spawning of small-mouthed bass in the aquarium at the Central Station of the U. S. Bureau of Fisheries in Washington. The fish were confined in the regular exhibit tanks having a glass frontage of 6½ feet by 3 feet extending back about 3 feet at the bottom and flaring to 7 feet at the top. The Washington City water supply was employed, the temperature running at 65 degrees. The supply was shut off during the spawning act.

The female whose actions were observed weighed close to 2 pounds and had been kept in the tank for several years. Spawning was first noticed about 1:15 p. m. on May 17, 1929, and continued intermittently until shortly after 3 o'clock when observations were discontinued. The distended abdomen of the female indicated that many eggs were yet to be discharged. The nest prepared by the males consisted of a circular space slightly over a foot in diameter from which all loose stones had been brushed, exposing the wooden floor of the tank.

The actual emission of the eggs covered a period of approximately 10 seconds and there were intervals of about 3 minutes or more between each deposition. Most of the time the female was accompanied by four males who kept close to her as she moved about in the vicinity of the nest. At each deposition of eggs she settled to the bottom and her body appeared to become rigid. Actual extrusion of the eggs was marked by a slight rapid vibration of the body and fins, being more noticeable in the partly flattened dorsal. At the start of this movement the fish was generally in a normal position, but by its conclusion she was generally turned partly on one side with the body bent in a slight arc. As the eggs were voided they had the appearance of a string of beads, but the movement of the fish and the water currents broke up the stimulated skein and dispersed the individual eggs over the bottom of the tank. As far as could be determined from 20 to 50 eggs were discharged at each emission. The eggs were white, opaque, and adhered readily to the gravel and rock work of the tank.

As the female settled to the bottom, each time the males attempted to arrange themselves parallel to and touching her. Apparently it made little difference whether they assumed a head-to-head or head-to-tail position. Milt was emitted either simultaneously or a few seconds following the appearance of the eggs. The milt was discharged in a thin whitish thread which held its structure until it was an inch or more in length and then was dissipated in the same manner

as the eggs. While a slight stiffening and vibratory movement was noted, it was much less pronounced than was the case with the female.

There was little tendency toward harrying the female by the males although one did seize her upper jaw in such a manner that his lower jaw was in her mouth. She was released immediately. There was some nipping and biting among the rival males, but much less than would be expected in view of their usual pugnacity. The following day one of the males had assumed control of the nest and was repelling invaders with the customary vigor. Eggs deposited in this tank in previous seasons have hatched successfully and produced several thousand healthy fry.

The paper by Reighard (Breeding Habits, Development and Propagation of the Black Bass in the Sixteenth Annual Report, Michigan State Board of Fish Commissioners, 1903–04) offers one of the most detailed descriptions of the spawning of bass. The observations at the Washington aquarium coincide in many points with Reighard's observations, but there are some points of difference, possibly due to the fact that the aquarium specimens were living under unnatural conditions. The Michigan papers cite intervals of thirty seconds between emissions, whereas at least 3 minutes intervened in the case cited above. He also states that eggs were emitted for a period of about five seconds, which was slightly less than noted by the writer.

The chief deviation was in the position of the female during and after spawning. Reighard mentions that she lies on her side while the eggs are emitted and may swim on her side during the interval between. The specimen noted above did not at any one time lie fully on her side, and the activity between spawnings was virtually normal, although marked by somewhat rapid respiration.

There is full accord with his observations regarding the mottling of both sexes and the red coloration of the eye of the male. While pointing out that the female is usually darker, he mentions one exception which was lighter in color than the male. Our observations agree with this exception. The presence of an excess number of males in the aquarium tank would very likely introduce modifications in the behavior of the fish which would fully account for the slight divergencies in the two observations.

FEEDING HABITS OF SPECKLED TROUT IN ONTARIO WATERS

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INTRODUCTION

At the meeting of the American Fisheries Society one year ago, Professor Harkness read a preliminary report upon the examination of speckled trout waters of this Province, which was begun in 1928. In presenting an account of the work which has been done since 1928, it was thought advisable to speak of one phase only, which has been studied in considerable detail, namely, the food of speckled trout in the natural condition, as shown by the contents of their alimentary tracts. The material for this study has been collected partly by the author, partly by members of the Toronto Anglers' Association and other fishermen, who have in many cases spent considerable time preserving the entrails of their catch. In all, the contents of about one thousand stomachs of speckled trout have been examined.

The study of stomach contents may serve three purposes:

1. If the food requirements of trout and the food available in any particular body of water be known, the first step toward determining its suitability for supporting a trout fishery has been taken.

2. If the food requirements of large trout and the food available in various trout habitats be known, sportsmen may have an explanation for the great disparity in the maximum size attained by trout in different waters.

3. If the differences in the food organisms taken by trout of various sizes and the distribution of these organisms along the course of a stream or in a lake, be known, fish culturists will have an accurate method of deciding where to plant fry, fingerlings, yearlings, or adult trout.

LIST OF TROUT FOODS

Vegetable matter: Consists of filamentous algae, bits of Chara, and aquatic seed plants, seeds and leaves of trees and grasses. These occur sporadically in trout of all sizes except the very smallest.

Worms: Fresh-water Oligochetes occur rarely.

Leeches: Several species are not uncommon in trout from slow streams or ponds.

Molluscs: Chiefly small snails of the genus Physa, but occasionally other genera, or small clams of the genus Pisidium.

Cladocera or Water Fleas: In streams Chydorus is a food of fingerlings under one inch in length. In lakes the large species Leptodora kindtii is commonly eaten by adult trout.

Copepods: Canthacamptus and Cyclops are common in the smallest trout.

Ostracods: The most important food of the smallest fingerlings.

Amphipods or Fresh-water Shrimps: Hyalella occasional throughout; Gammarus common in specimens from only a few localities.

Crayfish: An important food of trout in warmer streams, less important in ponds and lakes.

Centipedes and Millipedes: Occasionally found.

Spiders: Occur rather generally.

Hydrachnids or Water Mites: Occur occasionally in trout of all sizes, chiefly from ponds.

Aquatic Insects: These constitute the bulk of the food of all trout except the smallest (less than 1 inch long) and the largest (more than about 12 inches long). They may be taken in either the immature stage: larvae or nymphs, or in the transition stage: pupae or sub-imagoes, or in the adult stage. In many cases they are taken most readily when they are emerging from pupa or nymph to imago, or among mayflies from nymph to sub-imago.

The following orders have been found:

Plecoptera: Stone flies are not very common; "krugers" or large nymphs of the genus Perla, are most often found.

Ephemeroptera: Mayflies occur in trout from every habitat. In lakes and some streams the burrowing genera Hexagenia and Ephemera are abundant; in stony streams of moderate to swift current, Ecdyurus, Epeorus, Chirotenetes, Ephemerella, and Baetis are the principal genera; while in slow streams and ponds occur Blasturus, Callibaetis and certain others.

Odonata: Dragon flies are not an important trout food. Nymphs of Aeshna umbrosa or of Gomphus were occasionally found and rarely an adult Aeshna or Sympetrum was taken. Damsel fly nymphs and adults also rarely enter the trout diet.

Megaloptera: A few larvae and imagoes of Sialis, the alder-fly, and larvae of Chauliodes were taken.

Trichoptera: Caddis-flies are the most important insects in the trout's diet. In ponds and slow streams casebearing larvae of the Phryganeidae and Limnophilidae are the largest single item in the stomach contents; in stony streams net spinning larvae of Hydropsychidae are most frequent, and larvae of Chimarrha, Rhyacophila, Glossosoma, Polycentropidae and Hydroptilidae also occur.

Diptera: The midge family, or Chironomidae, is the family of true flies of most general occurrence. They are taken by trout of all sizes, but bulk largest in stomachs of fingerlings 1 to 2 inches long. In Chara ponds they are especially common, and even the large trout of the lakes retain the habit of ingesting some of the larvae. In the rapid brown-water streams of northern Ontario, however, they are greatly exceeded in numbers by the Simulid or black-fly larvae, which in spring are the big item in the food of the trout in those waters.

Other families of flies which occur are the crane-flies or Tipulidae, deer-flies or Tabanidae, and the phantom-larvae or Corethridae.

Coleoptera: Aquatic beetles are represented chiefly by the Haliplid genus Hydroporus, but species of Dytiscidae, Gyrinidae, Hydrophilidae and the curious genera Elmis and Psephenus are not uncommon.

Heteroptera: The true bugs found are principally waterboatmen of the family Corixidae but include also water-skaters, back-swimmers and water-scorpions of the families Gerridae, Notonectidae and Nepidae.

Terrestrial Insects: The food which trout take at the surface of the water is principally composed of land insects. They make up over 50 per cent of the total food of the trout of smaller rivers and brooks and in the fall are important in the larger streams, ponds and lakes.

The following orders occur:

Hymenoptera: Chiefly bees, ants and Ichneumonids.

Coleoptera: Beetles of many families were found; the dungbeetle, Amphodius, was perhaps most frequent.

Diptera: Of flies also, many families were represented. Noteworthy is a great swarm of Bibionids in the autumn of 1928, many of which were taken by trout in the northern streams.

Lepidoptera: Various caterpillars were not uncommon.

Homoptera: The principal families were Cercopidae, Cicadellidae and Aphididae—spittle-bugs, leaf-hoppers and plant-lice.

Heteroptera: Land species of true bugs are not very common, the stink-bugs or Pentatomidae being the only family deserving special mention.

Orthoptera: Grasshoppers and crickets occurred where the waters were close to open fields.

Fish: A good number of species of fish are known to live in the same waters as the speckled trout, and it is probable that most of them at times become the prey of the larger individuals.

The following species have actually been found in stomachs:

*Cisco—Leucichthys sp.

Speckled trout—Salvelinus fontinalis: Several cases of cannibalism were discovered.

Common sucker—Catostomus commersonii.

Creek chub—Semotilus atromaculatus.

Rosy-faced minnow—Notropis rubellus.

Common shiner—Notropis cornutus.

Trout-perch—Percopsis omisco-maycus.

Sculpin—Cottus bairdii.

*Sculpin—Cottus cognatus.

Five-spined stickleback—Eucalia inconstans.

*Nine-spined stickleback—Pungitus pungitus.

Species marked with an asterisk are recorded by Clemens (1924).

Amphibia: One trout from a northern river had taken a rather large frog. The author has also heard from a reliable source of a red-backed salamander (Plethodon cinereus) being found in a trout stomach.

Reptilia: One trout 7½ inches long had eaten and partly digested a snake. Though the reptile was a small one it exceeded the trout in length.

FOOD OF TROUT AT DIFFERENT AGES (TABLE 1)

Of the one thousand stomachs which have been examined, the contents of some three hundred, chiefly from cold Chara-covered ponds and lakes, have already been tabulated (Harkness and Ricker, 1929). They show that in such waters the principal foods are snails and aquatic insects, particularly caddis larvae; that as the size of the trout increases, so does the average size of their food organisms; and that there is a fluctuation in the numbers of each species of insect eaten, which is related to its time of emergence.

The data in Table 1 are for trout from streams of moderate to rapid current and having a stony bottom, with the exception of the first three groups, which were taken over a mud bottom not far from vegetation. Although the table does not include the smallest trout, and only small numbers of the very large ones, it permits of the following generalizations:

When trout fry first begin to feed, it is probable that they take Entomostraca almost entirely. The smallest which were examined, 0.8—1.0 inches long, were captured on June 7, 1928; 66 per cent of their stomach content by volume consisted of Entomostraca, made up of Ostracoda 36 per cent, Copepoda (Canthocamptus and Cyclops) 26 per cent, and Cladocera (Chydorus) 4 per cent. These are not plankton organisms, such as young bass eat, but rather benthos, i. e. animals living on the bottom or on plants. Ostracods are well known to be principally bottom organisms; Carpenter (1928) says: "Canthocamptus and other Harpactidae are not plankton species at all, but wriggle their worm-like bodies over stems of plants," and again, in speaking of the weedy border of a stream: "a few littoral species of Cyclops, such Cladocera as Chydorus, and Canthocamptus, . . . are found among the plants."

After reaching a length of about one inch, the fingerlings abandon their crustacean diet and turn to the stream insects, of which chironomid larvae are the chief, forming three-quarters of the food of those 1.0—1.5 inches long. At this size too they begin to take land insects, which fall into the water from above. Between 1.5 and 3 inches the number of chironomids taken falls off to 11 per cent and there is a great increase in both land and water insects, so that in 9 specimens all the important families except Plecoptera were represented. In fact, with the exception of spiders and a few hydrachnids, insects were the only animals eaten. The 3—4 inch class shows a

further reduction in chironomids, and a decided increase in may-fly nymphs and caddis-fly larvae, but is otherwise much the same.

In the stomachs of trout 4—6 inches long, crayfish make their first appearance, although the 20 per cent is probably too high for an average figure. With the bibionids mentioned above, they obscure, in the table, the importance of may-flies and caddis-flies, which should bulk as large as in the next length group. At 6—8 inches fish appear and at once take an important position. The aquatic black-fly larvae, may-fly nymphs and caddis larvae are the principal insects, while terrestrial animals have fallen off in number. In the 8—10 inch group caddis have increased, may-flies decreased in number, and land insects continue to decline.

The food of the large trout, 10—20 inches long, is chiefly crayfish and fish. Caddis larvae are the only insects of any account, totalling 48 per cent in the 12—16 inch group because of their abundance in a single stomach. Fish appear to be of more importance than crayfish, especially in the largest specimens.

Comparison of Food of Trout in Rivers, Ponds, and Lakes

Table 2 gives a comparison of the foods of large speckled trout from streams and from lakes in northern Ontario. Situated in a region of granitic rocks, these waters are deficient in lime and carbonates, and are acid or only slightly alkaline in reaction. Fish are the important item in both cases, comprising 76 and 87 per cent respectively of the total food. In the streams this is supplemented by crayfish and caddis larvae. In the lakes crayfish are less important, and the insects are mainly burrowing may-flies and midges. Plankton organisms are, however, present in the form of a few phantom larvae (Corethra) and numerous individuals of the cladoceran, Leptodora.

Table 3 gives the food of trout over 10 inches long in three types of trout waters of southern Ontario, where the water is rich in lime and carbonates, and rather strongly alkaline: (1) a shallow lake of 2 acres extent, with a low water temperature and a Chara-covered bottom, (2) a warmer and deeper lake of 25 acres extent, with a flora of Potamogetons, Nymphaea, etc., in the shallower areas, (3) rivers with moderate to swift current and stony bottom. In the warmer lake, fish were the only food of importance, in the rivers they made up about half of the total with crayfish the other half, while in the cooler lake neither of these animals was available and the trout took caddis and beetle larvae. It is probably due to the absence of these larger foods that the pond trout did not commonly exceed 12 inches in length, while in the other two situations they were known to reach 18 or 20 inches.

Summary

1. In Ontario streams with stony bottom, the food of speckled trout changes with increase in size from Entomostraca to chironomid

larvae, other aquatic and terrestrial insects, crayfish and finally fish. This series shows an increase in size of the food organisms with increase in size of the trout.

2. In lakes of northern Ontario, fish are the main food supply of trout over 10 inches long with plankton as the only other important element.

3. In lakes of southern Ontario also, fish are almost the entire food supply of the large trout. It would seem that although small Chara ponds produce trout food in great abundance, it is not of large enough size to support many trout over 12 inches in length.

Discussions and Conclusions

Few will dispute the fact, though many may not fully realize its significance, that one of the essential requirements of a good trout habitat is an abundant food supply. Any confirmation which this statement may need has been abundantly supplied in the course of this investigation. In ponds and streams where trout thrive, there has always been found a rich stock of invertebrate or vertebrate life; and conversely in waters where for any reason food is deficient, trout, if they occurred at all, were in poor condition and had nearly empty stomachs.

A closely related but more questionable matter is the maximum size which trout customarily attain in various waters. The results tabulated seem to establish a direct relation between size of trout and size of food organisms available. In waters where other fish and crayfish are rare or absent, the trout do not commonly reach as great a size as in waters where these animals abound.

From the study of the food of the smaller trout, recommendations for planting trout in streams may be made:

1. Fingerlings up to 1.5 inches long should be placed near muddy banks covered by 2–5 inches of water and with preferably a few weeds. In such places Entomostraca and small chironomid larvae are most abundant.

2. Fingerlings 1.5 to 4 inches long may be placed over a stony or weedy bottom, where aquatic insect larvae and nymphs are most abundant.

3. Yearlings 4 to 6 inches long may be placed in warmer streams where larger insects and crayfish are found, or in streams where aquatic insects are rather scarce, but having an abundance of terrestrial insect falls on the water.

In the tables which follow, the figures show the percentage by volume of the food item in question. A cross indicates that it was present in amounts of less than one half of one per cent of the total, while a dash indicates that it was entirely absent.

Acknowledgments

The writer is greatly indebted to Dr. E. M. Walker, Professor J. R. Dymond, Professor W. J. K. Harkness, Mr. F. P. Ide and other members of the staff of the University of Toronto for advice and assistance given throughout the course of the investigation. Many thanks are also due to members of the Toronto Anglers' Association and other individuals for preserving material from all parts of the Province.

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TABLE 1.

FOOD OF SPECKLED TROUT IN ONTARIO STREAMS

Length of trout in inches	0.8–1.0	1.0–1.5	1.5–3.0	3–4	4–6	6–8	8–10	10–12	12–16	16–20
Number of stomachs examined	6	14	9	12	47	64	31	12	9	6
Average volume of contents in cu. mm.	3.5	5.7	52	62	240	600	710	1730	2810	30,000
Vegetable matter	–	–	+	5	+	+	5	1	1	1
Leeches and Worms	–	–	–	–	–	+	–	–	–	–
Molluscs	–	–	–	–	1	1	2	1	–	–
Water-fleas (Cladocera)	4	–	–	–	–	–	–	–	–	–
Copepoda	26	1	–	–	–	–	–	–	–	–
Ostracoda	36	7	–	–	–	–	–	–	–	–
Fresh-water shrimps	–	2	–	–	+	–	–	–	–	–
Crayfish	–	–	–	–	20	2	3	31	28	10
Millipedes and Centipedes	–	–	–	–	+	+	+	–	–	–
Spiders	5	–	19	4	1	1	1	2	–	–
Water-mites (Hydrachnida)	–	–	+	+	+	–	+	–	–	–
ADULT AND IMMATURE AQUATIC INSECTS:										
Stone-flies	–	–	–	2	+	2	1	–	2	+
May-flies	–	–	3	11	7	19	8	+	+	–
Dragon- and Damsel-flies	–	–	11	–	–	+	4	–	–	+
Alder-flies and Chauliodes	–	–	–	–	+	1	–	–	–	+
Caddis-flies	–	–	2	29	12	16	25	8	48	+
Caddis larval cases	–	–	2	10	1	3	7	+	6	+
Midges (Chironomidae)	28	73	11	5	2	4	2	1	+	+
Other true flies	–	11	–	12	6	17	10	1	1	+
Beetles	+	5	3	6	1	1	3	–	–	–
True bugs (Heteroptera)	–	–	2	1	2	1	1	+	+	–
ADULT AND IMMATURE TERRESTRIAL INSECTS:										
Bees, Ants, Ichneumonids	–	–	1	1	3	4	3	1	–	–
Beetles	–	+	–	2	11	5	4	2	–	–
True flies	–	–	4	1	15	2	1	–	–	–
Caterpillars (Lepidoptera)	–	+	10	3	2	+	–	+	–	–
Bugs (Hemiptera)	–	–	14	1	6	2	1	+	–	–
Grasshoppers and Crickets	–	–	–	–	7	1	+	–	–	–
Unidentified insects	1	1	18	6	3	2	1	3	–	–
Fish	–	–	–	–	–	17	19	48	14	84
Frogs	–	–	–	–	–	–	–	–	–	3

TABLE 2.

FOOD OF SPECKLED TROUT IN WATERS OF NORTHERN ONTARIO

	Streams	*Lakes*
Length of trout in inches	10–20	10–16
Number of stomachs examined	13	32
Leptodora	–	7
Crayfish	11	1
Caddis larvae and adults	7	+
Other aquatic insects	2	4
Terrestrial insects	+	+
Fish	76	87
Miscellaneous	4	+

TABLE 3.

FOOD OF SPECKLED TROUT IN WATERS OF SOUTHERN ONTARIO

	Cold Chara pond 2 acres	*Warm lake 25 acres*	*Rivers*
Length of trout in inches	10–11	11–16	10—20
Number of stomachs examined	8	5	14
Vegetable matter	3	1	1
Crayfish	–	–	45
Caddis larvae and adults	41	+	5
Caddis cases	28	–	–
Other aquatic insects	27	+	+
Terrestrial insects	–	–	1
Fish	–	99	44
Miscellaneous	1	–	3

Discussion

Mr. Titcomb: I should like to ask Dr. Ricker in regard to the methods by which these trout were caught. If taken with the fly would there not be a difference in the contents of the stomachs in the days when the trout were rising?

Mr. Ricker: I have noticed this difference in one stream in particular when the trout were rising freely to the fly. I have not attempted to compare the trout taken on worms against those taken on flies in order to see whether there was a difference in the terrestrial insects.

STUDIES ON THE SEASONAL FOOD OF BROOK TROUT*

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It is the writer's intention to present data in this paper on, (a) monthly consumption of foods by brook trout (*Salvelinus fontinalis*) over a one year period, with (b) notes on food taken during spawning, (c) notes on the vertebrate food of brook trout, and (d) notes on internal parasites observed.

Monthly Consumption of Foods by Brook Trout

Table 1 gives lengths and dates of collection, by months, of the two hundred and fifty-one trout upon which these results are based. It will be noted that but few trout were obtained in February and March. This was due to the fact that roads to the trout streams became impassable with drifting snow, streams were frozen over and it was only with the greatest difficulty that the few trout were obtained in the smaller, warmer, head-water streams where the ice could be broken and a seine used. All the trout, including those taken by Mr. Hazzard, were caught in streams near Ithaca, N. Y., most of them from the Dusenberry branch of Six Mile Creek. Others came from Owasco Inlet, East Branch of Owego Creek, Peg Mill Creek, Hemlock Brook, Newfield Creek, Virgil Creek, Hay Brook and Enfield Creek. Part of the trout were caught with rod and line and part with a small trout seine of the type devised by Mr. H. C. White in Ontario.

The data are arranged in sequence by months. The foods eaten are given in percent by number to show selectivity of the trout. The number of times each occurred is listed and refers to the number of trout which had eaten each kind of food. Foods listed as "terrestrial" include all animals which do not live in or on the water, such as terrestrial insects (larvae, pupae, and adults), spiders, millipedes, centipedes, and earthworms, as well as the adults of aquatic insects which lead an aerial or terrestrial existence after emerging from the water. "Aquatic" foods include all forms which live in or on the water, such as larvae and nymphs of stone-flies, may-flies, caddis-flies, true-flies (Diptera), alder-flies, as well as water beetles, water-striders, salamanders, fish, crustaceans, and snails.

In tables 2, 3, and 4, the foods taken each month are given. These tables are largely self-explanatory, and only the more significant points will permit of discussion here. In January, February, and

*Collection of trout for stomach examinations was made possible through a permit issued to the writer by the N. Y. State Conservation Dept. Field work was begun in the month of April 1928 and continued that summer for the N. Y. State Conservation Dept., and completed in March 1929. Brown and rainbow trout were also taken for stomach examinations but data on these fish will be published elsewhere. Thanks are due the Conservation Dept. for their co-operation in this work and also Mr. A. S. Hazzard of Cornell University, who contributed his unpublished paper, "A short study of the vertebrate food of trout" for incorporation here. The writer is indebted to the Biological Laboratory, Cold Spring Harbor, Long Island, N. Y., for assistance during the latter stages of this work.

March it will be noted that the supply of terrestrial foods fell to a minimum. Trout during these months are almost entirely dependent upon underwater foods for their sustenance, though some terrestrial

TABLE 1

NUMBER, LENGTHS, AND DATES OF COLLECTION OF BROOK TROUT TAKEN EACH MONTH

Month	No.	Maximum length	Minimum length	Average length	Dates of collection
Jan.	13	6″	3″	4″	16th & 26th
Feb.	9	4″	3″	3½″	25th
Mar.	4	3½″	3″	3¼″	18th
Apr.	21	8½″	6″	7″	17th & 29th
May	10	8″	6″	7″	4th & 15th
June	25	7″	5″	6″	15th, 22rd, 25th, 27th & 28th
July	62	9″	3″	6¼″	2rd, 3rd, 9th, 10th, 12th, 16th, 18th, 23rd, 25th, 31st
Aug.	40	9″	4″	6″	1st, 2rd, 3rd & 29th
Sept.	18	9″	4″	6″	3rd, 14th & 29th
Oct.	18	7″	3″	5½″	6th, 12th, 20th & 30th
Nov.	19	8″	3½″	4½″	7th, 14th, 21st & 27th
Dec.	12	6″	3″	4″	11th & 27th
Total	251	Average 7.08	Average 3.8	Average 5.5	————

foods were taken by the fish in each of the colder months of the year. In January only two terrestrial insects, one adult fly and one adult beetle, occurred in two of the thirteen stomachs. Remaining foods were all under-water forms, such as may-fly, stone-fly, and dragon-fly nymphs, caddis-fly larvae and pupae.

In February, 37 adult caddis-flies constituted the land foods eaten during this month. These trout were collected on February 25. Field notes show that this day was bright and clear, with air at 45°F. No doubt this fine spell of weather stimulated a few caddis-flies to leave the water at this time. Perhaps if trout had been collected on a day when bad weather prevailed, the foods would have been entirely aquatic in origin. In March, one spider and one beetle were the only terrestrial foods eaten.

Trout were collected twice in December (table 1), on the 11th and 27th. The five trout taken on the first date contained the only terrestrial foods obtained that month. These consisted of leaf-hoppers, adult midges, and a few true plant bugs. The seven trout taken on December 27th contained nothing but submerged foods, terrestrial food apparently having been killed off or driven to cover by cold weather. From this we may conclude that December is likewise unproductive in land foods.

TABLE 2

FOODS CONSUMED BY BROOK TROUT DURING JANUARY, FEBRUARY, MARCH, AND APRIL

Foods	January						February						March						April					
	Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic		
	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring
Mayflies				1	0.63	1				18	14.75	5							24	13.26	5	77	10.43	12
Caddis-flies				88	55.34	10	37	100.0	4	86	70.49	10				32	66.67	5				348	47.16	21
True flies	1	50.0	1	21	13.21	9				6	4.92	3				13	27.08	3	120	66.30	3	262	35.5	16
Beetles	1	50.0	1	8	5.03	3				1	0.82	1	1	50.0	1	1	2.08	1	26	14.36	9	2	0.27	2
Stone-flies				6	3.77	2				5	4.1	3				1	2.08	1				10	1.36	3
True Bugs																			2	1.1	2	10	1.36	5
Ants, Bees and Wasps																			1	0.55	1			
Grasshoppers and Crickets																			1	0.55	1			
Water Springtails				25	15.72	1				5	4.1	2												
Alderfly Larvae										1	0.82	1										2	0.27	2
DragonflyNymphs				2	1.26	1																1	0.14	1
Spiders													1	50.0					4	2.21	3			
Mites																						1	0.13	1
Crayfish et al.				4	2.52	1																1	0.13	1
Snails and Clams				1	0.63	1										1	2.08	1				13	1.76	6
Fish or Salamanders				2	1.26	2																7	0.95	4
Fish Eggs																						4	0.54	3
Earthworms																			3	1.66	1			
Totals	2		2	158		31	37		4	122		25	2		2	48		11	181		25	738		77

TABLE 3

FOODS CONSUMED BY BROOK TROUT DURING MAY, JUNE, JULY, AND AUGUST

Foods	May						June						July						August					
	Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic		
	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring	No.	%	Times occur-ring
Mayflies	40	33.61	2	60	54.05	8	12	9.84	3	56	33.94	17	22	7.24	6	138	23.35	35	72	23.84	8	166	60.14	26
Caddis -flies				27	24.32	7	8	6.56	7	64	38.79	18	2	0.66	1	331	56.01	41	2	0.66	2	71	25.73	19
True-flies	4	3.36	4	9	8.11	5	6	4.92	4	29	17.58	12	41	13.49	12	46	7.78	21	103	34.11	17	12	4.34	7
Beetles	24	20.17	3	3	2.7	3	32	26.23	15	7	4.24	5	57	18.75	28	5	0.85	5	27	8.94	17	4	1.45	5
Stone-flies				2	1.8	2	4	3.28	1	3	1.82	3	4	1.32	3	16	2.71	7				8	3.0	8
Leafhoppers et al.							4	3.28	4				64	21.05	17				47	15.51	17			
True Bugs							7	5.74	2				8	2.64	5	2	0.34	2	5	1.66	3			
Moth Larvae							6	4.92	3				14	4.6	10				6	1.99	5			
Ants, Bees and Wasps							28	22.95	12				60	19.74	20				26	8.62	18			
Grasshoppers and Crickets							1	0.82	1				11	3.5	9				6	1.99	2			
Water Springtails																						3	1.01	1
Alder-fly Larvae				1	0.9	1										3	0.51	2						
Dragonfly Nymphs				1	0.9	1										5	0.85	5				2	0.72	1
Spiders							5	4.1	5				7	2.4	6				8	2.66	7			
Millipedes	15	12.61	1				2	1.64	1				9	2.96	6									
Centipedes							1	0.82	1															
Mites										1	0.61	1												
Crayfish et al.	1	0.84	1	6	5.41	4				4	2.43	4				40	6.77	14				9	3.26	9
Snails and Clams	3	2.52	3	1	0.9	1				1	0.61	1				4	0.68	3						
Fish or Salamanders				1	0.9	1										1	0.17	1				1	0.36	1
Fish Eggs																								
Earthworms	32	26.89	8				6	4.92	5				5	1.64	4									
Totals	119		22	111		33	122		64	165		61	304			591			302			276		

TABLE 4

FOODS CONSUMED BY BROOK TROUT DURING SEPTEMBER, OCTOBER, NOVEMBER, AND DECEMBER

Foods	September						October						November						December					
	Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic			Terrestrial			Aquatic		
	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring	No.	%	Times occurring
Mayflies	5	5.62	2	9	18.0	6	5	5.32	2	4	7.55	2				2	4.35	2				5	1.47	2
Caddis-flies	1	1.12	1	14	28.0	10				21	39.63	12	7	22.58	3	21	45.65	13				63	18.53	9
True Flies	11	12.36	4	7	14.0	4	2	2.12	2	6	11.32	5				2	4.35	1	16	16.5	3	38	11.18	8
Beetles	7	7.87	6	3	6.0	1	26	27.66	14	6	11.32	3	11	35.5	4	3	6.52	3	1	1.03	1	12	3.53	3
Stoneflies	1	1.12	1																1	1.03	1			
Leafhoppers et al.	34	38.20	12				32	34.04	9				4	12.9	4				75	77.32	2			
True Bugs	2	2.25	2	4	8. 0	4	1	1.06	1	3	5.66	2				1	2.17	1	3	3.01	1			
Ants, Bees and Wasps	3	3.37	3				1	1.06	1				4	12.9	3									
Grasshoppers and Crickets	23	25.84	12				22	23.41	11				2	6.45	2									
Water Springtails				11	22.0	2				10	18.87	1										210	61.77	3
Spiders							1	1.06	1				2	6.45	2				1	1.03	1	1 (Mite)	0.3	1
Millipedes	2	2.25	2				4	4.26	4															
Crayfish et al.										3	5.66	2				1	2.17	1						
Snails and Clams																						11	3.24	3
Fish or Salamanders				2	4.0	2										7	15.22	7						
Fish Eggs																9	19.57	1						
Totals	89		45	50		29	94		45	53		27	31			46		29	97		7	340		29

In April, however, after the weather had become warmer, terrestrial animals became active, and stomach examination of trout taken that month shows a large increase in land forms, though aquatic organisms still make up the bulk of their diet. The following months, May to November inclusive, terrestrial animals are abundant and supply a considerable portion of the food. Chart 1 shows graphically the comparative monthly consumption of terrestrial and aquatic foods. It will be noted that in May, August, September, and October, terrestrial foods exceeded aquatic foods in numbers (table 5). At the height of the summer season in June, July, and August, one might expect this to occur, as land forms are assumed to be most abundant at this time. Perhaps this assumption is erroneous, for certainly according to the stomach counts of these trout, land forms, or at least those which fall into the water and which the trout get, are actually more abundant during May, August, September, and October. Doubtless, part of the cause of the variation between land and water foods may be assigned to seasonal variations, weather conditions, and other factors which must be considered. Proof of this will await more detailed studies of larger series of stomachs taken during these months. However, according to these findings a surprising amount of land food is available during the fall months, least occurring in the winter months of December, January, February, and March.

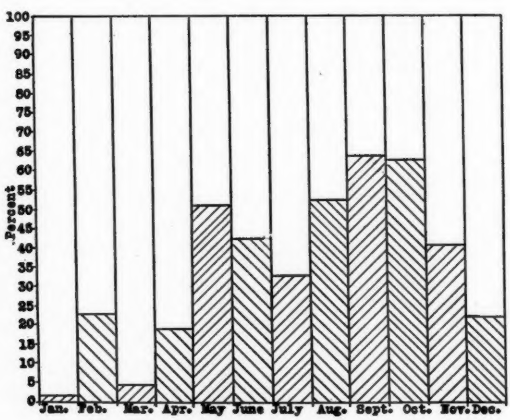

Chart 1.-Monthly comparison of terrestrial and aquatic foods consumed by brook trout.

-aquatic

-terrestrial

TABLE 5

MONTHLY CONSUMPTION OF TERRESTRIAL AND AQUATIC FOODS BY BROOK TROUT

Month	Terrestrial Foods		Aquatic Foods		Monthly total
	No.	%	No.	%	
Jan.	2	1.25	158	98.75	160
Feb.	37	23.27	122	76.73	159
Mar.	2	4.0	48	96.0	50
Apr.	181	19.70	738	80.30	919
May	119	51.74	111	48.26	230
June	122	42.50	165	57.50	287
July	304	33.97	591	66.03	895
Aug.	302	52.25	276	47.75	578
Sept.	89	64.03	50	35.97	139
Oct.	94	63.95	53	36.05	147
Nov.	31	40.26	46	59.74	77
Dec.	97	22.20	340	77.80	437

TABLE 6*

DOMINANT TERRESTRIAL AND AQUATIC FOODS SELECTED BY BROOK TROUT EACH MONTH

Month	No. of trout	Terrestrial Foods		Aquatic Foods	
		1st choice	2nd choice	1st choice	2nd choice
Jan.	13	——**	——	Caddis-fly larvae & pupae	Water springtails
Feb.	9	——	——	"	Mayfly nymphs
Mar.	4	——	——	"	Fly larvae and pupae
Apr.	21	Adult flies	Terr. beetles	"	"
May	10	Adult mayflies	Earthworms	Mayfly nymphs	Caddis-fly larvae & pupae
June	25	Terr. beetles	Ants, bees & wasps	Caddis-fly larvae & pupae	Mayfly nymphs
July	62	Leaf hoppers	"	"	"
Aug.	40	Adult flies	Adult mayflies	Mayfly nymphs	Caddis-fly larvae & pupae
Sept.	18	Leaf hoppers	Grasshoppers & crickets	Caddis-fly larvae & pupae	Water springtails
Oct.	18	"	Terr. beetles	"	"
Nov.	19	Terr. beetles	Caddis-fly adults	"	——
Dec.	12	Leaf hoppers	Adult flies	Water springtails	Caddis-fly larvae & pupae

*Derived from Tables 2, 3 and 4.

**Insufficient numbers eaten; choice not indicated.

Monthly Consumption of Terrestrial Foods

Table 6 lists first and second choice of land and water foods by months.

Considering land foods first, leaf hoppers were the dominant terrestrial insects eaten in July, September, October, and December and did not occur as second choice in any of the nine months for which data are listed. Adult flies were first choice in April and August and second choice in December. Terrestrial beetles were first in June and November and second in April and October. Adult mayflies were first in May and second choice in August. In May, high waters cut away the stream margins and washed many earthworms into the stream where they were eaten by the trout, forming the second choice for this month. In late summer grasshoppers became very numerous, forming second choice of the trout in September. Adult caddis-flies were never secured by these trout in sufficient numbers to constitute a first choice and they occurred only once as second choice, in November. Ants, bees, and wasps (Hymenoptera) were second choice in June and July. The bulk of the members of this latter named group were ants, both winged and wingless forms, bees and wasps occurring in the stomachs at infrequent intervals.

TABLE 7

SUMMARY OF EACH CLASS OF FOOD EATEN BY THE 251 BROOK TROUT

Food	Terrestrial		No. of times occurring	Aquatic		No. of times occurring
	No.	%		No.	%	
Mayflies	180	13.04	29	536	19.87	114
Caddis-flies	57	4.13	16	1,166	43.22	163
True flies	304	22.03	45	451	16.72	95
Beetles	213	15.44	98	55	2.03	34
Stoneflies	10	0.72	7	51	2.00	27
Leaf hoppers	260	18.84	62	0	0.0	0
True bugs	28	2.03	19	20	0.74	13
Ants, bees & wasps	123	8.91	57	0	0.0	0
Grasshoppers et al.	66	4.78	35	0	0.0	0
Water springtails	0	0.0	0	264	9.80	11
Moth larvae	26	1.88	18	0	0.0	0
Alderfly larvae	0	0.0	0	7	0.26	6
Dragonfly nymphs	0	0.0	0	11	0.41	9
Spiders	29	2.10	25	0	0.0	0
Water mites	0	0.0	0	3	0.01	3
Millipedes	32	2.32	14	0	0.0	0
Centipedes	1	0.07	1	0	0.0	0
Crayfish et al.	1	0.07	1	68	2.52	38
Snails & clams	3	0.22	3	32	1.19	11
Earthworms	47	3.41	18	0	0.0	0
Fish or Salamanders	0	0.0	0	21	0.77	19
Fish eggs	0	0.0	0	13	0.48	3
Totals	1,380	99.99	—	2,698	100.02	—

Summary of Terrestrial Foods

The left hand side of table 7 gives a summary of all land foods as eaten by the 251 brook trout. It will be noted that adult flies formed the largest single item of their terrestrial food diet, or 22.03% of total number consumed. Leaf hoppers were second, forming 18.84%; beetles third at 15.44%, while adult mayflies, ants, bees, and wasps, grasshoppers, and adult caddis-flies were fourth, fifth, sixth and seventh respectively. Other land forms such as spiders, moth larvae, millipedes, etc., while occurring occasionally, are not important items so far as a steady diet is concerned.

Monthly Consumption of Aquatic Foods

Of foods supplied from the water, caddis-fly larvae and pupae were the dominant forms consumed. These were first choice every month of the year except in May, August, and December where they occurred as second choice. The dominant genera of caddis-fly larvae found in the stomachs were *Hydropsyche*, *Goera*, *Neuronia*, *Neophylax*, *Leptocerus*, *Astenophylax*, *Limnophilus*, *Philopotamus*, and *Glossoma*.

Mayfly nymphs formed first choice of the trout in May and August and were second in February, June, and July. Mayfly nymphs commonly eaten belonged to the following genera: *Baetis*, *Ephemerella*, *Leptophlebia*, *Epeorus*, *Heptagenia*, with a scattering of *Tricorythus*, *Blasturus*, *Iron* and *Chirotenetes*.

Fly larvae and pupae (Diptera) were second choice in March and April and were third choice in January, February, May, June, July, August, October, and December. (Third choice not indicated in Table 6.)

The great majority were midge larvae (Chironomidae). Common genera found were *Orthocladius*, *Chironomus*, *Tanytarsus*, and *Tanypus*. Midge larvae, as noted by Johnston (1929), Clemens (1928), Needham (1903) and others, form a very large percentage of the food of small fish. The writer examined the alimentary tracts of four brook trout taken from Harbison's Pond at Highlands, N. C., ranging in length from six to eight inches. These fish were filled with midge larvae, as many as three hundred being taken from a single stomach. Only three other organisms were found, a few caddis larvae, one diving beetle, and one water boatman. In bulk, over 75% of the food of these trout was midge larvae. This further illustrates the importance of these organisms as food.

Other fly larvae common in the stomachs were *Eriocera*, *Tipula* (Tipulidae), *Simulium* (Simulidae), *Eristalis* (Syrphidae), *Atherix* (Leptidae), and *Chrysops* (Tabanidae).

Table 6 shows springtails (Collembola) to have been first choice in December and second in January and September. This might lead one to suspect that these insects are a rather important part

of trout diet. Just the reverse is true, however. Springtails are usually less than one-sixteenth of an inch in length with heavily chitinized bodies, and while they are often very abundant, they must contain a great deal of undigestible material, and on account of their size, are usually eaten only by small fish 1″–3″ in length.

Stone-flies (Plecoptera), both as nymphs and adults, when abundant, furnish considerable amounts of food. The stone-fly population of the streams in which these trout were collected was small and very few were taken by the trout. In some streams, particularly those in Western United States, stone-flies abound literally by the millions and supply enormous amounts of excellent trout food.

Summary of Aquatic Foods

Of all aquatic foods consumed (table 7), caddis-fly larvae and pupae were the dominant forms eaten by the 251 trout. These were taken in larger numbers than any other food, forming 43.22% of all aquatic organisms eaten. Also they were found in 163 of the 251 trout. May-fly nymphs were second in importance and formed 19.87% of total aquatic foods. Aquatic fly larvae and pupae were third and made up 16.72% of aquatic foods.

Twenty-nine crayfish were taken from twenty-seven stomachs or approximately 11% of the fish examined. Trout containing crayfish averaged 6½ inches in length which is one inch longer than the average for all the trout. This shows that the larger foods are eaten by the larger fish. Fish containing crayfish ranged in length from four to nine inches. In bulk, crayfish averaged 32% of the food eaten.

Other crustaceans found in the stomachs were shrimps, *Gammarus fasciatus;* scuds, *Hyallella knickerbockeri;* and copepods. These were relatively scarce and can be considered as unimportant here.

Miscellaneous forms including snails and clams, dragon-fly nymphs, water striders, and water boatmen, and aquatic beetles, were scarce and can be considered as minor sources of food. However, it was noted that these forms were taken more commonly in the winter time than in the warmer months of the year. Scarcity of terrestrial forms probably drives trout to accept less palatable foods during this time of year.

Table 8 shows that over a period of one year, approximately two-thirds (66.16%) of the foods eaten by brook trout are supplied by the water while about one-third (33.84%) comes from the land. These findings agree in general with those previously determined by the writer (Needham, 1928) from examination of one hundred and forty-seven brook, brown and rainbow trout stomachs taken in June, July, and August, wherein 56.66% were aquatic foods, and 43.34% from the land. Where the winter months are included in the data, naturally the pecentage of aquatic forms runs higher.

TABLE 8

SUMMARY OF FOODS CONSUMED BY BROOK TROUT

	No.	Percent
Terrestrial	1380	33.84
Aquatic	2698	66.16
Total	4078	100.00

Table 9 shows the very large part insects contribute to the diet of trout. Land insects formed 91.81% of the land foods, while aquatic insects formed 94.92% of the aquatic foods, showing at once that insects formed the largest single food element in their diet.

TABLE 9

INSECTS COMPARED TO OTHER LAND AND WATER FOODS CONSUMED BY BROOK TROUT

	Terrestrial		Aquatic	
	No.	Percent	No.	Percent
Insects	1267	91.81	2561	94.92
Other foods	113	8.19	137	5.08
Total	1380	—	2698	—

Of the 4,078 items eaten by the 251 trout, 93.87% of this number were either land or water insects, the remaining 6.13% being miscellaneous foods supplied both by the land and water. Of the 4,078 articles of food, the average per individual trout was 16.24 items. This figure may or may not be of any value but is given merely to show the average number of items found per trout.

That group of insects which contributed the largest number of individuals was the caddis-flies (Trichoptera). Larvae, pupae, and adults formed 30% of the 4,078 items eaten. Fly larvae, pupae, and adults (Diptera) were second, forming 18.51%. May-fly nymphs and adults (Ephemerida) were third at 17.41%. Together, these three groups made up two thirds or approximately 66% of all the foods. It may be concluded, then, that the caddis-flies, true-flies, and may-flies are the dominant foods of brook trout in the streams of central New York State wherein these studies were conducted.

Fish and Salamanders Eaten by Brook Trout

Table 7 shows that twenty-one fish and salamanders were taken by nineteen fish, or 7.50% of the two hundred and fifty-one trout. Table 10 gives the complete data on each trout in which either of these foods occurred.

TABLE 10

FISH AND SALAMANDERS EATEN BY BROOK TROUT

Length of trout	Food	%*
6″	1 minnow	35
5″	1 two-lined salamander	100
6″	1 salamander	90
4″	1 minnow	85
4″	1 salamander	95
6½″	1 minnow	90
6½″	1 salamander	45
5″	1 Jefferson's salamander	75
3″	1 two-lined salamander	30
5.75″	1 salamander	40
8.3″	2 sculpins	50
6.7″	1 sculpin	50
7.02″	2 sculpins	47
7½″	remains of small fish	2
6.1″	remains of one sculpin	25
7″	1 minnow	50
8½″	1 minnow	80
6.8″	1 two-lined salamander	85
8″	1 minnow	35

**Percent by bulk.*

It will be noted that these foods constituted from 2% to 100% of the food taken, in each case the average being around 58%. The average length of the trout which had taken these foods was 6.2″, which is 0.7″ longer than the average for the 251 trout (5.5″). Many workers have noted that these foods are generally eaten by the larger trout, though as the above table shows, small trout occasionally take them. Of the twenty-one vertebrates thirteen were fishes and eight were amphibians. Most of these fish were the common sculpin, *Cottus bairdii*, which is abundant in the brook trout waters about Ithaca. The two-lined Salamander, *Eurycea bislineata*, another trout brook inhabitant, was the commonest amphibian found in the stomachs. Identification to genus was not always possible and depended upon the extent to which the digestive juices had destroyed the specimens. Vertebrates should not be classed as a major food of these trout. They were of too infrequent occurrence in the stomachs and were not a daily part of their diet. However, due to their large size and relatively little indigestible material present, vertebrates probably furnish more nourishment per individual than any other forms that trout feed upon. Caddis-fly larvae and pupae, while much smaller in size, make up in numbers for their lack of size, and being easy to secure from day to day, constitute one of the staple foods upon which trout live.

Intestinal Parasites Observed

Of the thirty brook trout examined by Mr. Hazzard in his study of the vertebrate foods of trout, six were hosts to tapeworms while three were infested with roundworms. No distinct pathological effects were observed. In the brook trout examined by the writer, one was host to a tapeworm, many had a few roundworms and a great abundan ce of parasitic flatworms were taken from the stomachs. The flatworms were identified by Dr. Faust of Tulane University and found to be *Crepidostomum cornutum* (Osborn) and *Allocreadium lobatum* (Wallin). One six inch brook trout taken December 11, 1928, contained fifty of the first named parasite. This fish was in good condition and showed no evident pathological symptoms from such a heavy infestation. *Allocreadium lobatum* was never abundant in the stomachs but was often found in the same gut tract with the other species. Both of these parasites were most abundant in the trout during the months of October and December. In trout taken during the spring and summer none was observed. However, parasitic roundworms were observed regularly during the warmer months of the year. Very young forms of parasitic flatworms are known to live in may-fly nymphs and possibly the trout became infested by feeding on these forms.

Food Consumption During Spawning

Brook trout taken from the spawning beds November 7, 1928, when spawning was at its height, all contained food. The stomachs were far from being completely distended but there was always some food present in both males and females. Immature, non-spawning trout taken at this time had eaten about the same proportionate amounts of food as the spawners. Stomachs taken before and after spawning showed no evident differences from those taken during spawning. From these observations it seems probable that feeding is unaffected by the spawning period.

It should be noted that at this time of year, in late October and early November, lowered water temperatures naturally tend to slow up feeding. Stomachs taken during the summer months are often completely distended with food, while in the colder months the average distention of the stomachs by food was estimated at about 25% to 35% of capacity. Rainbow trout taken by the writer when the water temperature was 37°F all contained food but in relatively small amounts, the stomachs being distended about 10% of capacity. Brook trout taken when the water was 40°F all contained small amounts of food.

That brook trout can be cannibalistic was illustrated by the stomach contents of one 7″ male fish taken November 14, 1928, just after spawning was over. This contained nine brook trout eggs, no other foods being present in the stomach. No other brook trout containing eggs in the gut tract was observed.

Summary

1. The stomach contents of 251 brook trout were taken over a twelve months period and the results tabulated in numbers and percents.

2. In December, January, February, and March trout are largely dependent upon water-bred foods. During the other months of the year terrestrial animals supply a large proportion of their food.

3. Adult flies (Diptera), leaf hoppers (Cicadellidae), terrestrial beetles (Coleoptera), and adult may-flies (Ephemerida), made up the bulk of the land foods consumed. Of aquatic foods, caddis-fly larvae and pupae (Trichoptera), may-fly nymphs (Ephemerida), and fly larvae and pupae (aquatic forms) supplied the bulk.

4. Of all foods consumed over a twelve months period, approximately two thirds were supplied by the water and one third supplied by the land.

5. Insects formed over 90% of total foods, over 94% of aquatic foods, and 91% of terrestrial foods.

6. Three orders of insects, namely the caddis-flies (Trichoptera), flies (Diptera), and may-flies (Ephemerida), supplied two-thirds of the insect food eaten.

7. Fishes and amphibians were found to play a minor role as food in the trout examined.

8. The presence of parasitic roundworms, tapeworms, and flatworms was noted, but no pathogenic effects were observed in the fish harboring these forms.

9. The spawning period in brook trout seems not to abnormally slow up feeding though there is a natural decrease in the amount of food taken at this time of year due to lowered water temperatures.

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Discussion

Mr. Titcomb: Were all your trout netted, Dr. Needham?

Dr. Needham: No, part of them were caught on fly, part on bait, and part in nets. On January 16th I took brook trout on bait, using dead brook trout eggs. The

temperature of the air was 41° F and the water, 39° F. I tried to make it a point always to take the trout where I had previously taken bottom studies. I also ran my drift net, which strained out all the material that drifted down in the water of the stream. Then I knew what was floating in the water, what was present on the bottom, in addition to getting the trout from the same section of the stream.

Mr. Titcomb: These papers have brought out the fact that the large trout subsist for the most part on forage fishes; but we do not protect those minnows against the ravages of the anglers, who take usually a great many more minnows than they need for live bait. We also have the commercial bait dealers to contend with, who should be regulated by license. It is an exceedingly important phase of conservation work.

With all this knowledge of the foods of trout, how are you going to increase fish food? You can increase your terrestrial insect food in some instances by encouraging shade along the banks, but the question is how to increase aquatic life in trout streams.

Dr. Needham: I do not think anybody has so far found any method of increasing the aquatic life in trout streams. In the New York Stream Survey one problem in 1927 was the productivity of plant vegetation in trout streams. We found that there was nine times the food in a stream that had plant beds than there was in ordinary drift bottom. Undoubtedly plants offer more shelter and support for the aquatic organisms. Great possibilities in the improvement of trout streams lie in the introduction of proper vegetation. No attempts have yet been made to improve the bottom foods in flowing waters that have no plant beds. In my previous work I found that the riffles in trout streams were five times richer in food than the pools.

Mr. Titcomb: Every now and then some one wants to introduce from one watershed to another the caddis or some other fly. We know that certain streams are inhabited by one species of fly more than by another. We cannot introduce the caddis fly into a stream where it does not exist and have it stay there.

Dr. Needham: I think a great amount of money has been wasted in trying to introduce organisms into trout waters to which they are not adapted. Numbers of game clubs have bought different kinds of aquatic organisms in a desire to improve their streams. They should find out what is already there and after ascertaining the biological and physical factors, see whether some adaptable organisms can be found. Furthermore, you are apt to introduce incompatible or predacious forms which kill off more food than is produced.

Dr. Hubbs (Michigan): With reference to the matter of the introduction of food, I had an interesting experience in Michigan in 1927. The Huron Mountain Club, which has a considerable number of fine lakes containing trout and other fish, attempted to improve the fish supply in those waters by the introduction of certain food species. They bought various quantities of Amphipods from a commercial firm over a period of years. In a study of their lakes I found Amphipods in only two lakes, and they were the only two in which the Amphipods had not been planted. It is more important to improve the natural conditions in the streams and lakes than to rely upon the introduction of foreign food supplies.

In Michigan we are conducting an experiment of a highly practical nature in an effort to improve the productivity of the trout streams; namely, the introduction of barriers into trout waters. Several hundred snags are being placed in the streams at various points. We are keeping track of each snag to see how much shelter it provides for the trout and to what extent the trout are thereby increased. It is a complicated

problem, involving, besides the more obvious factors, the question of increase in the productivity of the food in the stream. When a barrier is introduced into a stream, an effort is made to add a considerable amount of fine brush to the major logs and other material, which encourages the growth of caddis and other insect larvae. Many of the barriers were placed in such a way as to gouge out a hole that already exists or to throw the current to one side. There is an accumulation of finer debris which is washed out and on this weed beds should develop.

PROF. HARKNESS: It seems to me that the anglers in the formation of angling clubs are showing us the way to increase the productivity of the streams. Some of the Ontario clubs which have dammed the headwaters of the streams now have from five to fifteen acres of water where formerly there was nothing but a stream and are taking from the increased area more and larger trout than formerly could have been taken throughout the whole length of the stream. As Dr. Hubbs points out, work is being done in Michigan practically along the same line, with a modification to increase the productivity along the whole length of the stream. As soon as streams are dammed, vegetation increases, particularly chara, and on the chara we find all the forms which trout relish.

MR. TITCOMB: I want to utter a word of warning about having too many ponds in a stream. In our state, where conditions are extremely artificial, there is an epidemic of pond building. A pond is put in at the head-waters of the stream, with the result that the stream below that point has a higher temperature. When you cut off the head-waters with dams, creating ponds of say from two to ten acres, you may have entirely spoiled the rest of the stream as a trout stream. You may have one main stream down through a valley with a number of feeders, all of which are contributing cool water in the summer. When occasion requires, the trout will leave the main stream and go into these feeders, which is impossible if all the feeders are dammed at the headwaters by private ponds.

PROF. HARKNESS: That is true, but we are up against the condition of getting absolutely no trout over seven inches throughout the whole length of a stream. The making of ponds in the upper reaches of the stream permits the raising of a considerable number of fish to legal size. As Mr. Titcomb suggests, a great deal of discrimination must be exercised in this connection.

CONTROLLING FACTORS IN THE DISTRIBUTION OF GAMMARUS

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The value of Gammarus, or fresh-water shrimp, as a food for speckled trout has been recognized for some time and considerable work has been done on their life history and distribution.

Embody (1912) has worked on the details of life history, food, and reproduction of four species of amphipods, *Gammarus limnaeus*, *Gammarus fasciatus*, *Eucranyonyx gracilis* and *Hyalella knickerbockeri*, and Kendall (1921) has discussed at some length the possibility of their use in fish culture, but neither of them has dealt with the ecological factors which control the geographical distribution of the various species. The only work which has been done in this connection is that of Titcomb (1927), who found the distribution, in the New England States, of the two species *Gammarus fasciatus* and *G. limnaeus* to be dependent upon the degree of hardness of the water.

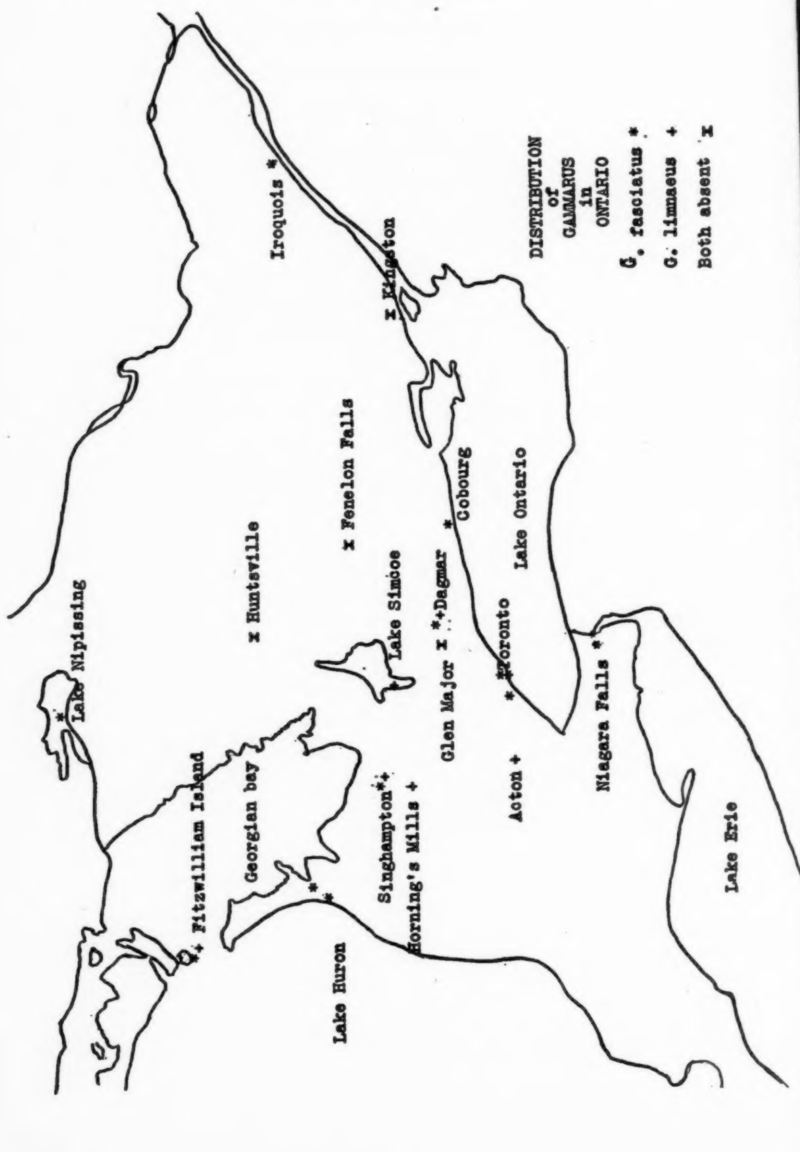
The present investigation is being carried on by the writer for the Biological Board of Canada to determine the natural distribution of the two species as found in Ontario, the factors which limit this distribution, and the possibility of introducing them into waters, in which they do not now occur, to augment the food supply of the brook trout.

For the purpose of this study, the Province of Ontario may be divided into two major divisions on a geological basis; eastern and south-western Ontario, in which much of the rock is calcareous, and the waters are consequently hard and alkaline; central and northern Ontario, in which the basic rocks are granites and gneisses, and the water is, for the most part, soft and acid.

During the course of the investigation, streams and ponds in various parts of the Province have been visited and analyzed carefully for physical, chemical and biological factors which might have a controlling influence upon the distribution of *Gammarus*. Some time was spent in the central region, among the soft water streams, but the larger part of the work has been carried on in the southern part of Ontario, where the water is hard.

The Natural Distribution of Gammarus in Ontario

So far as present records show, the distribution of *Gammarus* in central and nothern Ontario is limited. Only eight specimens have been reported from this region. Seven of these were *G. limnaeus* and were taken by Dr. F. B. Adamstone, of the Ontario Fisheries Research Laboratory, in Lake Nipigon in 1921. The eighth was taken by Mr. J. P. Oughton in Lake Nipissing in 1929, and although badly damaged had the general characteristics of *G. fasciatus*. These


DISTRIBUTION
of
GAMMARUS
in
ONTARIO
G. fasciatus *
G. limnaeus +
Both absent x
Iroquois *
Kingston
Fenelon Falls
Huntsville
Lake Nipissing
Lake Simcoe
Glen Major
Dagmar
Cobourg
Lake Ontario
Toronto
Niagara Falls
Acton +
Fitzwilliam Island
Georgian bay
Singhampton
Horning's Mills +
Lake Huron
Lake Erie

records would indicate that a more thorough search may reveal the presence of a scattering of *Gammarus* throughout this region.

Throughout the southern and eastern part of the Province, both species have been found in many widely separated localities, and in each locality the occurrence is decidedly local. Both species have been reported from Fitzwilliam Island, Georgian Bay, and both have, on one occasion, been taken together by the writer, but in the other habitats examined each species has been present alone.

The accompanying map of Ontario shows the localities in the southern part from which each species has been recorded. *G. fasciatus* is indicated by an asterisk and *G. limnaeus* by a cross.

The controlling factors have been placed for consideration in three groups, physical and chemical factors, vegetation, and enemies.

As all of the localities from which *Gammarus* have been reported have not been visited, analyses of all of these habitats cannot be given. Those which have been visited have all been similar in several respects, and quite different from the average stream in localities where *Gammarus* have not been found.

Table 1 gives the analyses of various localities where *Gammarus* have been taken, and also of four regions where they have not been found, in spite of careful examination. Each is the analysis of a definite habitat in the locality named and is representative of the streams and ponds of that locality. The temperatures given for the first four localities are winter temperatures and are naturally low at this time of year.

The first habitat listed, Horning's Mills, is a spring-fed lake of about twelve acres area. It contains a large number of trout, which supply most of the eggs for the hatchery of Mr. L. C. A. Strother. *G. limnaeus* are fairly abundant and form about ten per cent of the food of the trout. The chief vegetation here is *Chara*, and it is among the branches of this plant that the shrimp are found. As this lake is spring-fed, the bottom temperature remains low throughout the year, seldom, if ever, rising above 18°C. to 20°C.

At Toronto, *G. fasciatus* have been taken throughout the winter in Grenadier Pond, High Park, and in a small pond on the edge of Lake Ontario which is fed by the outlet of Grenadier Pond. Both of these ponds are thickly grown up with vegetation, *Chara* in Grenadier Pond and *Elodea* in the Lake Shore Pond. *G. fasciatus* were abundant here until March, when their numbers began to decrease, and during the summer no specimens have been found. Both ponds were shallow, consequently showing a steady rise in the maximum daily temperature as the summer advanced.

The other four habitats listed in which *Gammarus* have been taken are either springs or spring-fed streams with a maximum summer temperature of 12°C.

In all of these habitats from which *Gammarus* have been listed, vegetation consisting of *Chara*, cress or *Elodea*, and in one case at

Acton, dead leaves, was very plentiful. Gammarus have not been found in the course of this investigation in any location where either living or dead vegetation was not readily available.

An examination of the chemical analyses shows only slight differences in composition and certainly does not show any variation which could be held responsible for the limited distribution either of the genus or either species.

A comparison of the analyses of Fenelon Falls and Kingston habitats with the others does show one very marked difference, that of higher temperature, which is common to nearly all the streams of these regions. There are few springs and the temperature in the streams varies from 20°C. to 30°C. In other respects they resemble those where *Gammarus* do occur, having comparable chemical composition, volume, rate of flow, and containing *Chara* and *Elodea*. A thorough search of both of these regions failed to show the presence of *Gammarus* of either species, although *Hyalella* was abundant, which would indicate that temperature is here the limiting factor. Temperature also appears as a definite controlling factor in the regions in which *Gammarus* are found, as they are confined to the colder parts of the streams.

The Huntsville habitat is included in the table as an example of a trout stream in the acid waters of the granitic region. The temperature is low, but in this stream, and all others in the same area which were examined, the only vegetation present was some small clumps of an aquatic moss. No *Gammarus* were found in any of the waters of this region.

A third controlling factor of importance is the presence of trout. Any attempt to introduce *Gammarus* into waters containing a large number of trout and only a relatively small amount of food will be much less likely to succeed than where the food supply is greater than necessary for the number of trout present. An example of this may be had in the ponds of the Glen Major Fishing Club, located about forty miles from Toronto. An attempt to introduce *Gammarus* into one of the ponds was made in May, 1928, and was apparently unsuccessful, as none have been seen since. On July 8, 1930, several *G. limnaeus* were placed in a screen cage eight inches by twelve inches by twelve inches high, and supplied with *Chara* from the pond. This cage has been visited at intervals and mating pairs have been found at every visit, the last visit being five weeks from the date of introduction. This would indicate that water conditions are suitable for *Gammarus* in these ponds when protection is given.

Summary

1. Ponds, streams, and small lakes in various parts of the Province have been examined for physical, chemical, and biological factors which might exert a controlling influence upon the distribution of *Gammarus*.

TABLE 1

CHEMICAL ANALYSES OF GAMMARUS HABITATS

Locality	Nature of habitat	Date	Temp. ° C.	O_2 % Saturation	Bicarbonate*	Hardness*	pH	Species
Horning's Mills	Spring lake	Nov. 15/29	6	95.5	216		7.7	G. limnaeus
Toronto	Pond	Nov. 19/29	6.5	113	213	200	7.7	G. fasciatus
Dagmar	Spring stream	Nov. 20/29	4					G. limnaeus and
		(July 8/30	10)	99	210	200	7.5	G. fasciatus
Acton	Spring	Nov. 26/29	8		246		7.5	G. limnaeus
Singhampton	Spring	June 11/30	9	114	200	256	7.4	G. limnaeus
Singhampton	Spring stream	June 13/30	9.8	91	182	200	7.6	G. fasciatus
Glen Major	Spring pond	June 28/30	8.2	102	168	200	7.7	Both absent
Fenelon Falls	Creek	June 3/30	18	114	162	220	7.5	Both absent
Kingston	Enclosed bay	July 22/30	21		124	157	7.5	Both absent
Huntsville	Spring stream	May 27/30	7	94	12	68	Low	Both absent

*Bicarbonate and hardness are expressed as parts per million $CaCO_3$

2. Of these factors, temperature, vegetation, and presence of enemies alone appear to control the distribution.

3. So far as we have been able to determine, the chemical composition of the water does not appear to control the distribution of the individual species in any way.

4. *G. limnaeus* are found only in springs, spring-fed streams, or spring-fed lakes where the maximum temperature is low. *G. fasciatus* will live at higher temperatures, but appears to avoid high temperatures when possible.

5. When conditions of optimum temperature, and suitable vegetation are to be had, the waters of southern Ontario are uniformly suitable for the introduction of *Gammarus*.

6. When a preliminary introduction, in cages, has shown that water conditions are satisfactory, introduction on a practical scale may be undertaken with considerable hope of success.

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Titcomb, J. W. 1927. The fresh-water shrimp for replenishing food in trout streams. Trans. Am. Fish. Soc., 1927, pp. 150–159.

Discussion on Mr. Pentland's Paper

Dr. Hubbs (Michigan): In confirmation of Mr. Pentland's map of the distribution of Gammarus and Hyalella in Ontario I might remark that I made twenty examinations of all the different types of streams I could find in northern Ontario between and including Lake Timagami and Lake Remi, north of Lake Huron and as far north as half way to James bay. I did not see a single specimen of Gammarus. Practically all those waters were in the granite area. In Michigan we have no hard waters in a good deal of the trout area, but when we do get a hard water trout stream full of chara we are almost sure to get Gammarus.

MORE ABOUT THE FRESH-WATER SHRIMP

John W. Titcomb

Superintendent, State Board of Fisheries and Game, of Connecticut

In the Transactions of the American Fisheries Society for 1927 the writer presented a paper on the freshwater shrimp, which was concerned with the kind of waters in which the fresh-water shrimp thrive, as compared with the waters in which they do not appear to find a congenial habitat. It was demonstrated that the far-famed Caledonia shrimp (*G. limnaeus*) is confined as to its habitat to hard waters, i. e. waters heavily impregnated with lime and magnesium. The species also appears to require waters of a low temperature, or such as are congenial to the Salmonidae.

Another species slightly smaller than the Caledonia shrimp (*G. fasciatus*) was found to be abundant in many waters of a very slight hardness and capable of enduring high temperatures. Embody reports finding the *G. fasciatus* in waters of about 86 degrees. The introduction of *G. fasciatus*, therefore, stands a much better chance of producing favorable results than *G. limnaeus* when introduced to new waters, unless there is a definite knowledge that such waters are heavily impregnated with lime.

The *Hyalella knickerbockeri*, very generally distributed not only in cold water trout brooks but also in waters of a very high temperature, was dismissed from the discussion as not of sufficient size and abundance to be considered for general distribution in trout streams for the purpose of improving food conditions.

The publication of this article has resulted in a considerable correspondence and much additional information has been collected. The opinion that the Caledonia shrimp is only suitable for hard limestone waters has been confirmed by additional reports from as far west as the Pacific Coast. The waters of both the Rocky Mountain Range and the Sierra Nevada and Cascade Ranges appear to have much limestone water where the *G. limnaeus* is abundant.

A stream at Holderness, New Hampshire, which was examined by the writer, contained numerous shrimp of such size that he, before having them identified, thought them to be either *G. fasciatus* or *G. limnaeus*. Upon identification by both Dr. Philip Garman and A. T. Campbell it was found that these larger shrimp are the Hyalella knickerbockeri. There were specimens at least three-eighths of an inch long. Information from other sources indicates that in some places, under favorable conditions, the *H. knickerbockeri* is quite abundant and constitutes an important factor in food for fishes, both trout and bass. It is believed, however, that for trout waters which are not of sufficient hardness to warrant planting the Caledonia shrimp, it would be best to use the *G. fasciatus* for the reason that it is very generally of larger growth than the *H. knickerbockeri* and

because in very rare instances is the *H. knickerbockeri* found in large numbers and of a size approaching that of *G. fasciatus*.

Dr. Juday in a letter states that his experience has all been with the *H. knickerbockeri*, and that it is found in the soft water lakes of northern Wisconsin as well as in the hard water lakes of the southern part of that State. He adds that it gets a little larger in the hard water lakes than in the soft water ones. This information about the *H. knickerbockeri* is related because it is felt that this species should be given a more prominent place in the menu of fishes than was given in my original paper.

In an attempt to run down all reports that the *G. limnaeus* may be found in soft water a report was received from Peekskill, N. Y., that a bay of the Hudson River at Peekskill contained an abundance of *G. limnaeus*. Furthermore, samples of the waters submitted to Dr. Emmeline Moore proved to be soft. Upon investigation it was found that both *G. limnaeus* and *G. fasciatus* were abundant where fresh and salt water mixed. Three streams emptied into the bay. Wallace Pond Brook, containing very hard water, is inhabited by *G. limnaeus* only. Marrycroft Brook—which discharges soft water into the bay—is inhabited by *G. fasciatus* only. The Croton River, which has a combination of both fresh and salt water, is inhabited by both *G. fasciatus* and *G. limnaeus*. A chemical analysis of the water, made by Prof. C. R. Hoover of Wesleyan University, showed the presence of large amounts of calcium magnesium in the bay water, i. e.—211 to 500 P. P. M. Comparing these with the Marrycroft Brook water, we find a very much smaller amount of calcium magnesium present, i. e.—62 of calcium and 22 magnesium P. P. M. Wallace Pond Brook, which is a combination of fresh and salt water, shows 66 P. P. M. calcium and 46 P. P. M. of magnesium. From this data it will be seen that the *G. limnaeus* may be looked for almost anywhere in tributaries to rivers like the Hudson where at high tide there is a setback of salt water. It appears that the salt from the ocean water has the same effect as to hardness as the lime formations of the inland waters and that *G. limnaeus* thrives under such conditions and may afford a very reliable source of supply for stocking other waters.

A simple method (and one invariably used by the writer) of ascertaining whether shrimp are present in certain waters is to pull out a bunch of vegetation, dripping with water, and turn it over on a board or flat rock exposed to the sun. The vegetation should be carefully observed for the movement of insect larvae and other animal life. If present, the shrimp are readily discovered. The exposed surface of the board or rock may further show the presence of shrimp in the water which has dripped from the vegetation. If the first clump does not disclose the presence of shrimp, additional vegetation should be obtained at various spots and examined.

If shrimp are present, identification of the species may then be

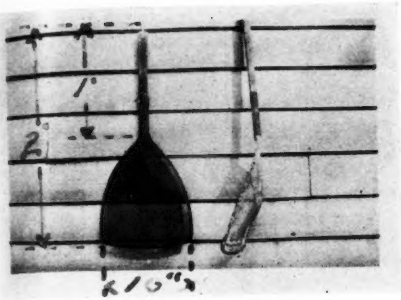


Fig. 3.

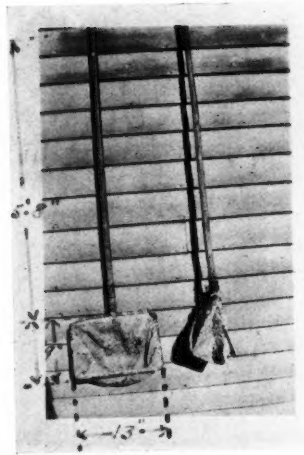


Fig. 4.

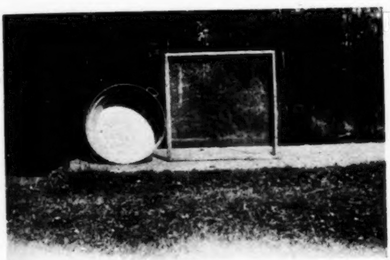


Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8. Habitat of Caledonia Shrimp

made by microscopic examination of the third uropod. The third uropod is the caudal appendage (Figure 1). On *G. limnaeus* (Figure 2, B) the hairs are plumose or branched like a feather, while on *G. fasciatus* (Figure 2, A) the hairs are not plumose.

To those contemplating the introduction of shrimp to new waters it may be stated that analyses of waters collected in different parts of the United States show that shrimp grow in waters which contain lime and do not grow in waters where lime is absent. Waters that contain 1 part per million of lime (CaCo3) will support some *H. knickerbockeri.* Waters that contain from 3 to 5 parts per million of lime (CaCo3) are suitable to stock with *G. fasciatus* and *H. knickerbockeri. G. limnaeus* are only suitable for waters which contain about 200 parts per million of lime.

Mr. H. K. Annin of Caledonia has kindly described his method of capturing the Caledonia shrimp for the purposes of stocking other waters. Similar methods may be used for obtaining the *G. fasciatus* in the soft waters where it abounds.

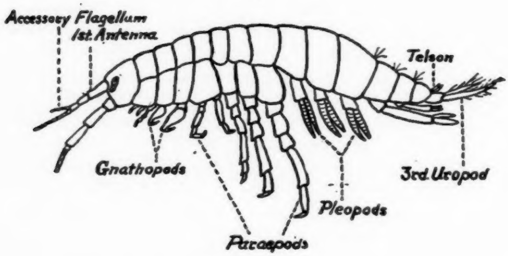
The collection of fresh-water shrimp is accomplished with long and short handled dip nets supplemented, when necessary, with an ordinary iron garden rake. A common wash tub and wire screen are used for separating them from the aquatic vegetation and debris.

The shrimp habitat varies with the seasons and environment. Accordingly the equipment of both short and long handled nets and rake is required. The short handled net has a handle of about one foot and a wire frame, oval on the two sides and slightly curved on the end (Fig. 3). Fine, flexible wire cloth, preferably of copper, with a mesh approximately nineteen to the inch, is sewn to the frame with copper wire. To collect very young shrimp a mesh still smaller is required. A slight sag of about one inch at the center and maximum point of curvature is given to the net.

If the shrimp are on the bottom in gravel or fine sediment or moss, several quick forward and backward thrusts with the net serve to dislodge them and facilitate the collecting operation. Then, by careful washing, the silt and other soluble debris are removed, by working the net backward and forward in the water. The residue containing the shrimp is then dumped into a pail which is at hand. After the desired number of pails are filled the contents are carefully worked over a suitable wire screen which allows the shrimp to drop through into a collecting basin (Fig. 5).

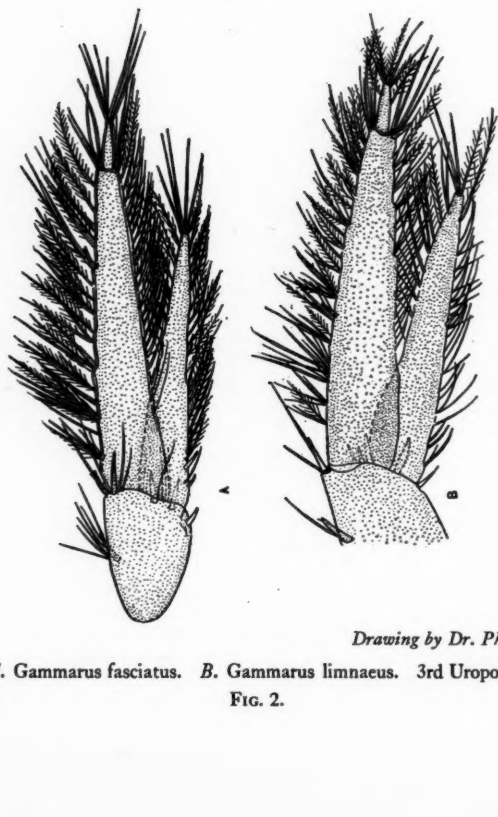
Not infrequently are shrimp found in watercress and floating aquatic plants. In such instances the net is thrust under them, worked backward and forward and up and down. This operation may be hastened by shaking the plants, causing the shrimp to drop onto the net. It is well to repeat this operation several times in one spot. If there is a current to the water better results are obtained by operating against the current.

In deeper water a long handled net is used (Fig. 4). This is made



Gammarus

Fig. 1.



Drawing by Dr. Philip Garman

A. Gammarus fasciatus. *B.* Gammarus limnaeus. 3rd Uropods.

Fig. 2.

of fine mosquito netting with a deeper bag to prevent the escape of the shrimp while the net is being raised to the surface. The operation is similar to that of the short handled net.

Occasionally the shrimp are found in thick growth which prevents successful operation of the collecting nets. In this case, such plants are dragged out with an ordinary iron pronged garden rake onto a platform on a boat or some floating device. The collection is then transported in suitable receptacles to the separator; or, if more convenient, the collection can be made directly onto the separator and the separating operation carried on repeatedly. The platform, if used on a boat, should be water tight, have two retaining sides to it, and be so tilted, with an open end projecting over the gunwale of the boat, as to allow drainage water to run off quickly.

The separator (Fig. 6) may consist of an ordinary wash tub, preferably galvanized iron, and a wooden frame with its bottom covered with galvanized wire of size four meshes to the inch. The frame, generally square with sides about four inches high, is placed on top of the tub. A quantity of plants or debris from which the shrimp are to be separated is placed on the screen to an amount which can be easily manipulated. This is then spread out in a thin layer over the screen surface, and frequent hand tappings cause the shrimp clinging to the wire to drop through into the collecting basin which should have two or three inches of water in it. This is an operation requiring some care and patience. The screen is then dumped; a further quantity of plants placed upon it and the operation repeated. Some of the finer debris will naturally pass through the screen and be collected in the tub with the shrimp. The shrimp can be separated from this by carefully pouring the water through one of the collecting nets. If some shrimp still remain in the sediment after the first operation, it should be repeated.

The collection can then be retained in floating boxes with wooden sides and wire bottoms of a mesh fine enough to prevent the escape of the shrimp. The boxes should be placed in a tank or trough through which an ample supply of pure cold water is constantly flowing. If several days are to elapse before shipment or planting is made, a quantity of suitable aquatic plants should be placed in the boxes to furnish food supply.

The number of shrimp in a shipment is obtained by counting out one thousand in a pan and using this known quantity as a guide in estimating the total number to be shipped.

Shipment can be made in cans equipped with ice containers such as are ordinarily used in the transportation of trout. A suitable moss, preferably fontinalis moss, is placed in a can which is filled about two-thirds with water and the shrimp then added to it. From three to four thousand shrimp, depending upon air temperature at time of shipment, generally constitute the capacity of a single seven gallon container (Fig. 7). If weather is warm the container should

be properly iced, and if necessary an additional supply sent along with the shipment for re-icing en route. In cold weather the water in the cans should not be allowed to freeze to any appreciable extent. Spring and fall, when the weather is cool, are the safer shipping periods. Under suitable conditions, a trip of forty-eight hours without change of water, re-icing, etc., can be made with safety. Shipment should be met promptly and the shrimp planted without undue delay. The contents of a single container should be distributed at several points, preferably where springs or spring brooks come in and where there are proper water plants to afford cover for the shrimp. Periodic investigations during the year following the planting should disclose the success of the effort.

Wm. H. Rowe of West Buxton, Maine, whose ponds are inhabited by *G. fasciatus*, writes that his waters contain millions of shrimp. They rise at night and feed on the surface vegetation, drift to the outlet and in the outlet tanks where he has no trout they accumulate in such great numbers that he has been able, by the use of a fine wire screen, to dip a pint or more of clear shrimp.

SOME OBSERVATIONS ON THE EASTERN BROOK TROUT (S. FONTINALIS) OF PRINCE EDWARD ISLAND

H. C. White

Biological Board of Canada

For some years experiments on the planting of trout fry have been carried on in Forbes' Creek, Prince Edward Island, by the Biological Board of Canada. During the course of these experiments we have had the opportunity to make a few observations on the life history of the trout in their natural habitats. In this paper, we have not attempted to give a full account of these observations, but merely to refer to some interesting points regarding the habitats and life history of the speckled trout of the island.

Prince Edward Island, the smallest of the provinces of Canada, having a length of only one hundred and fifty miles and a maximum breadth of thirty miles, lies in the Gulf of St. Lawrence off the coast of New Brunswick. The bed rock of the island is a red sandstone which is comparatively light, having a specific gravity of 1.8. There is no evidence of glacial drift over the larger part of the island. The soil, which is very porous and red in color, is composed mostly of disintegrated sandstone. The subterranean water level is not deep and permanent flowing springs are plentiful. On account of the porous condition of the soil, fertilizers are rapidly washed out and it is necessary for the farmers to repeatedly fertilize their lands. This is probably one of the reasons for the fertility of the streams and ponds. Masses of vegetation grow in the waters, and fish foods, especially the larvae of aquatic insects, are abundant.

In the waters of the island, the adult speckled trout have no fish enemies or rivals except in those waters where eels occur. There are few species of fishes which permanently inhabit the fresh waters, and with the possible exception of the golden shiner, which may have been introduced, as it has been found in one lake only, there is no indigenous species which is restricted to fresh water. Atlantic salmon enter the streams to spawn and the young remain in the streams during the parr stage, but they are not serious competitors of the trout. Besides the eels and salmon, three species of sticklebacks and one species of Fundulus inhabit the fresh waters, and at their spawning times, several anadromous fishes enter the streams. Practically all the permanent fresh-water habitats contain trout, even those shallow weedy ponds which one would consider fit only for sunfish or bullheads. The comparatively low air temperature which seldom reaches 80 Fht. undoubtedly makes it possible for trout to survive in such places.

The trout which live permanently in the fresh waters are locally known as stream-trout or pond-trout to distinguish them from those superior speckled trout which are caught in the sea waters or when they have returned to the fresh water from the sea. Besides differ-

ences in colour and body proportions of the sea-run trout and the stream-trout there is a considerable difference in their habits. The sea trout may cover a wide range in its wanderings whereas a stream-trout may remain for years within a very limited area. One marked stream-trout mentioned in our report of 1928, which was seined from its home pool in Forbes' Creek in 1926–27–28, was taken again this year from the same pool. Besides this trout, which was marked by removing the adipose fin and is readily distinguished from other trout as it has a deformed maxilla, twelve other trout, which were marked in 1928, were taken again this year from a small section of stream to which they had been returned after marking. In contrast to this behavior, the sea-run trout may run into the estuaries with the flood tides and return to the deeper water with the ebbing tides. When following the tides in the estuaries we have found them travelling in shoals. The extent of their wanderings at sea is not known but they are taken by anglers along the shores at distances of several miles from any stream mouth. Many of them ascend the streams before the spawning period but all the females entering with the spawning run do not spawn the year they enter the stream.

At spawning time the sea-run males show a brilliant translucent pink colouration with fainter dark markings where the stream or pond males are deep red with dark markings. The spots and mottlings which are very obscure on the sea-run fish when taken in salt water become more defined and brilliant during the spawning period. The eggs which average smaller in size than those of the stream or pond trout are generally deeply coloured.

In Forbes' Creek, most of the sea-run trout spawn on two spawning areas about forty rods above tide water. A few stream trout use these areas and many sea-run fish use the areas farther up stream where the most of the stream-trout spawn, but we have never observed a sea-run trout mated with a stream-trout. For several years we have made observations on these areas and find that the areas selected for spawning are where spring water enters the stream through the gravel of the stream bed. By taking temperatures around a spawning area the limits of the spring seepage may be outlined and it is found that these define the area selected by the spawning trout. We have taken temperatures in connection with a number of these spawning areas and the following example is typical of the results. In Forbes' Creek on a rapid which is eight rods long, some sixty fish were working over a section of the rapids approximately fifteen feet in length but they were using no other part of the rapids. On November 25th, 1926, temperatures were taken as follows: Air 27.2 Fht.; running water ten feet above spawning area, 32.5; three inches in gravel ten feet above area, 35.4; running water at bottom over area, 36.0; three inches in gravel at edge of area, 38.8; three inches in gravel ten feet below area, 36.0 three inches in gravel in the spawning area, 40.4. These temperatures show that whereas the

stream water was near the freezing point the trout were depositing their eggs in water which was 40.4 Fht. The trout select these areas whether the spring enters on a rapids or at the bottom of a pool and in one location we have found them spawning over a spring area covered by four feet of pond water. As the gravel has a low specific gravity and there is an upward pressure of spring water in the spawning areas, they appear soft and one may readily thrust his hand deep into the redds.

The male trout work over the gravel for some days before the appearance of any females on the spawning areas. This working of the redd by the males probably serves in removing much of the silt from the gravel and washes out most of the aquatic insect larvae which might attack the eggs. The females do not frequent the spawning areas until they are ready to spawn, but numbers of them may often be found in nearby pools. After depositing her eggs, the female may work for several days piling gravel over the eggs. This is accomplished by turning upon her side and making quick vigorous strokes against the gravel on the up-stream side of the redd. Although the males aid in making the depression in which the eggs are laid we have never observed them assisting in the covering of the eggs. While the female is covering the eggs the male is constantly busy chasing away other males. While the male was engaged in chasing away another male we have, on three occasions, observed small males darting over the redd and seizing the female by the ovipore. Spawning females often show abrasions around the ovipore and we have attributed these to the small males. It would appear that this is a means of getting eggs to eat similar to that employed by an eel when it attacks a female trout. After the eggs are covered both male and female may remain for a week or more near their redd, but they soon become less aggressive toward intruders. The females leave the spawning areas, but many spent and battle-scarred males may be found over the spawning areas for a considerable time after the spawning season.

An analysis of the stomach contents of trout taken off the spawning areas reveals the fact that large numbers of eggs may be eaten by both males and females. The stomach contents were removed from a number of trout without injuring them. This was accomplished by inserting a glass tube of suitable size into the gullet and then exerting pressure over the stomach. The stomach content was forced through the tube into a dish. To remove the entire stomach content it was sometimes necessary to inject water into the stomach through the tube and then force the water out. Stomach contents were taken from trout which was seined from a spawning area in the south branch of Forbes' Creek. Trout were taken on November 17th, December 6th, and 9th, 1927. In all, forty stomach contents were examined from this redd. Of these, thirty-five were males, four females and one immature. Three of the males had no eggs in their

stomachs, but 598 eggs were removed from the stomachs of the thirty-two. The largest number found in a single male was 97, the average was 14.2. Of the four females taken from this redd three contained eggs in their stomachs. The total number of eggs eaten by the females was 89, the highest number from an individual 60, the average 22.2. The one immature fish contained 22 eggs. From the difference in size and colour of eggs taken from the stomach of an individual it was evident that they were the eggs of several different females. Spawning areas such as those mentioned above are used by succeeding pairs of trout from late October to late December or even into January, and the late-spawning trout dislodge many of the eggs deposited by those preceding them. It is probable that the eggs which are washed out in making new redds form a large part of the eggs which are eaten. In spite of the egg eating by the trout the spawning areas, by the end of the season, are found to be well filled with eggs.

Contrary to the general conception, we have found that the fertility of naturally spawned eggs compares favourably with that obtained by artificial fertilization. Two of our observations may be cited as follows: On November 24th, 1926, we observed a ten-inch female trout accompanied by a ten and a half inch male over an excavation in a spawning area. The following day the redd was covered and the female was engaged in working more gravel over the eggs. Both male and female were taken on a baited hook. The female contained nineteen ova which had not been extruded. A fine-meshed net was placed below the redd and the gravel was carefully removed with the hands. The eggs from the redd were washed into the net. 452 eggs taken from this redd were placed in screen containers in a trough at the Southport hatchery. From these eggs there was a hatch of 347 fry or 79%. The loss includes infertile eggs and those dying from injuries which they received in the process of removing them from the gravel. In another test naturally fertilized eggs were placed in a screen container filled with gravel and buried in the redd. This experiment yielded a hatch of 66%.

In determining the fertility of naturally spawned eggs it is important that the eggs should be removed from the redd within a few hours after spawning, and they must be removed very carefully or practically all will die from injuries which they receive.

While removing eggs from a spawning area on the first of January this year we found newly laid eggs in the upper layers of the gravel whereas in the deeper layers eggs were in the process of hatching. Eyed eggs were found buried in the gravel at a depth of more than a foot. Many of these eggs in the deeper layers are distorted by the pressure of the gravel but they produce normal fry. Dead eggs in the spring water of spawning areas do not become fungussed and we have taken dead eggs from the redds during the month of June in a good state of preservation.

Many fry with the yolk sacs absorbed may be found in the redds before the spring freshets, which generally begin in March, but we have not found them out of the redds until after high water. Our observations indicate that they emerge from the redds during a freshet and that after emergence they either migrate down stream or they are carried by the current. After the flood water has cleared so that observations may be made, thousands of fry may be found below the redds, their numbers decreasing as one travels farther from the redd. In the east branch of Forbes' Creek after a spring freshet we have found them distributed down stream for nearly a mile but we could find no fry above the spawning area. After being distributed in this way, there is very little migration till they have attained a length of 1½ to 2 inches. Although fry may remain in the redd for some time after the yolk sac is entirely absorbed, many fry emerge from the redds with the yolk sacs only partly absorbed. We have examined the stomach content of many newly emerged fry and find that those with the yolk sacs only partly absorbed contain food organisms comparable to those found in fry with the yolk sacs entirely absorbed.

Thirty-one fry were collected below the spawning area in the east branch of Forbes' Creek on March 24th, 1927. Of these, 13 had not absorbed the yolk sac, 7 had the yolk sac about half absorbed and 11 carried less than one-half of the yolk-sac food store. All of these fry had considerable fat in the fat reservoir along the intestine. Two of those carrying part of the yolk sac had no food in the stomach or in the intestine and two had food in the intestine but none in the stomach. Thirteen of the 31 specimens had the yolk sacs completely absorbed and one of these had no food in the stomach but some in the intestine. Of the 26 which had food in their stomachs 21 contained Chironomid larvae. Copepods were found in the stomachs of 8, Simulium larvae in 2, Ephemera nymphs in 2, Oligochaetes in 2, Collembola in 1, larvae of Trichoptera in 1, Ostracod in 1 and sand particles in 4.

The averages of the percentage bulk in the various stomachs were as follows: Chironomid larvae, 69.26%; Copepods, 12.78%; Simulium larvae, 4.42%; Ephemera nymphs, 3.94%; Oligochaetes, 1.36%; and miscellaneous, 8.23%. The analysis of the food of this collection of trout fry shows a high percentage of Chironomid larvae. This we have found to be true of other collections of newly emerged fry.

Discussion

Mr. Cobb (Connecticut): The commercial trout dealers are taking eggs from some of these sea going trout and mixing them with their stock. I notice Mr. White says that the sea going trout do not mix with the stream trout in spawning time. I wondered if Mr. White could say what effect this mixing will have on our trout.

Mr. White: I might go still further and say that there are many physiological

races of speckled trout, and that we may be trying to introduce one physiological race into a stream to which it is not adapted.

MR. CATT (New Brunswick): In determining the percentage of eggs that were naturally fertilized, did you take those that were in the redd.

MR. WHITE: Yes.

MR. CATT: Are you including the eggs that are not found in the redd?

MR. WHITE: I have no data on the number of eggs which these fish laid. It is obvious that it is impossible to know beforehand how many a fish is going to lay. In the instance which I cited of the ten-inch female, I took the number of eggs from the redd, which was not much short of what she should lay.

MR. CATT: Are you sure that in this particular case where you took the 500 eggs out of the redd, it was the spawn of one female?

MR. WHITE: From the size and color of the eggs, and the fact that no other female had been seen over this area, I concluded that they were the eggs of the one female.

MR. TITCOMB (Connecticut): In the Province of Quebec, where the fishing is largely in lakes rather than streams, the majority of the trout spawn in the shallow shore waters in contradiction to the belief of many anglers that trout always ascend the streams for spawning. As you travel along the portages you usually follow the stream from one lake down to the other, and in but rare instances do the trout spawn in these streams. I think you will find that they enter the streams from an upper lake only when there is the spring seepage, to which Mr. White has referred. They seek the lake shallows because there is a seepage of spring water in those shallows. When the surface water gets low enough to affect the temperature of the spring water the trout will go there to spawn. Sometimes this does not happen until the ice has formed over the entire pond, and then large schools will rush in, deposit their eggs, and depart immediately. They do not stay as long as they do in the streams as described by Mr. White. The devastation from cannibals under these conditions is simply appalling. I had the opportunity by leaning over a rock on the edge of a frozen lake to watch one pair of trout spawning. There were seventeen trout which had already spawned awaiting to feast on the eggs of the pair which were on the nest.

MR. CATT: I understand that one trout was taken three years in succession from one pool. Was there any physical barrier to the ascent of the fish from that pool?

MR. WHITE: It returned to that section for three years. Even after the flood which cleaned out my entire experiment in 1927 it was still in that pool. There were no barriers to its ascent until a dam was reached one-quarter of a mile up stream. It came to the pool about the same time each year.

MR. RODD (Canada): Is there anyone here who has definitely determined the percentage of natural fertilization in the eggs deposited by one trout or any number of trout?

DR. EMBODY (New York): I think Mr. White has come as near to it as anybody. It does not make any difference how many eggs you have so long as you have the percentage. If you know the approximate number of eggs the trout will lay then you can arrive at an approximate figure.

MR. RODD: Is it not also true that unfertilized eggs may not live through until the time you make the determinations? The life of unfertilized eggs is not, as a rule, as long as the life of fertilized eggs.

DR. EMBODY: Possibly Mr. White could tell us what was his index for determining the fertility of the eggs.

Mr. White: I did not have any index for fertility except the actual hatch from the entire lot of eggs.

Mr. Rodd: At what time of the year did you get the eggs from the redd?

Mr. White: Immediately after spawning.

Mr. Rowe (Maine): How long does the female trout require to deposit the eggs?

Mr. White: I have watched a large number of spawning trout and I have never seen the female actually extruding the eggs.

Mr. Rowe: I have been told, and I think there may be some truth in it, that a female trout may be several days depositing her eggs. Of course fertilization has to take place practically at the time of deposit, so that I hardly see how a percentage of part of the eggs would hold true for the whole number.

Mr. White: Do you not think that the male accompanies the female throughout her whole spawning period?

Mr. Rowe: I think he does, but if the eggs were extruded over a period of several days he might be away from the female at the time some of them were deposited.

Mr. White: Do you think that would be economy in nature, for a female to be spawning when the male was away?

Mr. Rowe: Nature is very wasteful in her methods.

Dr. Field (Massachusetts): I think the point brought out by Mr. White with regard to the physiological races is important. In Sandwich Harbor, Massachusetts, we used for many years sea trout and figured we got the best eggs from them, but we have never been able to follow the results after planting. I am wondering if it would not be possible to find some distinction in the number of chromosomes.

Dr. Davis: I have been interested in Mr. White's account of the spawning habits of trout, because there is a striking similarity to those of the Chinook salmon which I studied quite carefully a number of years ago in the State of Washington. The spawning habits of the two species are almost identical. I have seen female salmon spawning without any males around. Their absence did not seem to make any difference.

Mr. White: Did you see any eggs actually extruded?

Dr. Davis: No, but I saw the female going through the motions for hours without any male around.

Mr. White: The movements which she makes in the act of covering the eggs may have been mistaken for spawning movements.

Dr. Davis: I watched with field glasses, and while I did not see the eggs actually extruded, the movements were precisely the same as though the male was present. In most cases there were several males around, but in one or two instances I did see them spawning with no males in the vicinity. I wanted to ask Mr. White if he had been able to find any relationship between the temperature of the water and the emergence of the fry from the redds. Some observers claim that the fry remain in the gravel until the temperature of the water reaches a certain point.

Mr. White: I think there is something in that idea. In some cases the food store, which is in the form of fat along the intestines, is also practically gone, yet the fry emerge from the gravel with a considerable part of the yolk-sac attached.

Mr. Rodd: Are you satisfied that no eggs were extruded while the accompanying male was chasing other males away?

Mr. White: The female was engaged in covering the eggs while the male was chasing the other males away; that is her function, while the function of the male is to keep the other males away.

MR. RODD: Could the trout of a particular brook be improved by introducing different trout which grow to a much larger size?

MR. WHITE: That would have to be determined by experimentation. Whether they would adapt themselves to the spawning conditions or establish themselves is another question.

MR. RODD: Our experience is that new races when introduced, in a few generations take on the characteristics of the native race.

MR. WHITE: Is it not possible that within a few generations after the outsiders have been introduced only the natives are left?

MR. RODD: It is quite possible.

MR. CATT: If you have never actually seen the extrusion of the eggs from the female, how do you know that the movements which you maintain are the action of covering the eggs with gravel are not those associated with the laying of eggs?

MR. WHITE: Because there were no eggs observed in the water and from the fact that the female had only nineteen eggs left in her, yet for some time she continued those motions.

MR. CHARLES LINDSAY (Gaspe): I have often seen the female extrude her eggs, and it is not the same movement at all as that of covering the eggs with gravel. I personally think that the percentage of eggs fertilized by nature is not as large as Mr. White has indicated, but I have not any actual experiments which give definite figures.

MR. JULL (Toronto): It is not necessary for the male to be present just when the eggs are extruded, because we have found by microscopic examinations of eggs taken from the nest in the wild condition that the microphyllum is open for the acceptance of the milt spermatozoa for thirty minutes.

FURTHER PROGRESS IN THE SELECTIVE BREEDING OF BROOK TROUT AT THE NEW JERSEY STATE HATCHERY

Charles O. Hayford, *Hackettstown, N. J.*, and
George C. Embody, *Cornell University, Ithaca, N. Y.*

Trout breeding experiments were started in the New Jersey State Hatchery in 1919 and a preliminary report on the progress of the work appeared in the Transactions of the American Fisheries Society for 1925. At that time it was indicated that an apparent increase in the average resistance of trout to at least one disease, Furunculosis, had resulted from three generations of selective breeding, the selections having been brought about through a natural elimination of non-resistant individuals by the disease itself. There was also noted a marked increase in the rate of growth in the third generation which, it was believed, resulted from a selection of the largest breeders.

Both strains designated as A and B in the last report have now been carried through to the fifth generation, and it seems desirable to record the more recent developments.

In deriving the fourth and fifth generations, selections have been made of fewer individuals. Not more than twelve outstanding pairs among several hundred breeders have been used in the origin of any one experimental group. The basis of selection has been chiefly size and coloration although in the last selections attention has been given to the mortality during the egg stage and to the number of eggs produced by each female.

The outstanding developments during the past five years may be enumerated as follows:—

1. Continued increase in the rate of growth resulting in larger fingerlings and breeders.
2. Marked increase in the average number of eggs produced by each female at the first and second spawnings.
3. Gradual increase in the mortality during the egg stage. Experiments are now under way in an attempt to reduce this mortality.

Table I. Showing Increase in Growth, Egg Production and Mortality During Egg Stage

Generation	Length in Inches of Females Nov. 2nd. year	Average Number Eggs per Female	Number Females Stripped	Mortality to Eyed Egg Stage
A_1	7–10	272	638	38%
A_2	9–12	246	745	42%
A_3		256	765	56%
A_4	10.5–13.75	1164	102	36.3%

4. Although a high state of resistance to furunculosis and a somewhat less marked resistance to octomitiasis have been developed there are other hatchery diseases caused by *Gyrodactylus*, *Chylodon* and gill bacteria to which later generations seem quite as susceptible as ordinary trout.

Increase in Rate of Growth

Continued increase in the rate of growth is indicated by the size of breeders at the date of first spawning, that is, November of the second year. Trout of this age are often designated as yearling breeders. If reckoned from the date of impregnation, they are two years old.

In Table I, it will be noted that the first generation breeders measured from 7 to 10 inches long. This was increased to 9 to 12 inches in the second and to 10.5 to 13.75 inches in the fourth generation. These measurements refer to females only. A few of the fourth generation males were found to be 14.5 inches long.

Individuals of the fifth generation will not reach sex maturity until November, 1931. However, 59 fingerlings from eggs taken November 1929 and measured on November 10, 1930, ranged from 5.8 to 8 inches long. These fingerlings were not selected. They were merely dipped out of the rearing pond and hence are fairly representative. It is quite probable that neither the largest nor the smallest were captured.

It is well to point out that the individuals of each generation were reared in the same ponds and otherwise, so far as possible, under identical conditions. We believe that the increase in size has been due almost entirely to the selection of eggs from the largest breeders.

Increase in Egg Production

One of the most surprising developments was the enormous increase in the average number of eggs produced per female. This was first noticed in the fourth generation females maturing in 1929 when 102 produced 118,728 eggs, an average of 1164 per female. This compares with an average of 272 in the first generation.

The surprising fact is that this sudden increase appeared without any conscious attempt to bring it about through the selection of high producing individuals. The presumption is that high egg yield is linked in some manner with a high growth rate and, if true, one would expect the largest females to produce the highest average number of eggs.

In order to test this supposition, 53 first spawning females representing all size groups were stripped into as many pans. The total length of each fish and the number of eggs produced were determined. The latter was accomplished by first counting the eggs in one liquid ounce and then, after determining the volume of the lot, the total number was calculated. This was done in the case of each female. A summary follows in Table II.

TABLE II. RELATION OF LENGTH OF FEMALE TO NUMBER OF EGGS PRODUCED AT FIRST SPAWNING

Number Females	Total Length in Inches	Total Number Eggs	Average No. Eggs per Female	Variation in No. Eggs Within the Group
4	13–13.75	6597	1649	950–2040
18	12–12.75	21,849	1213	629–1786
26	11–11.8	29,713	1142	612–1632
5	10.5–10.75	4579	916	743–1224

It would appear that as the length of the fish increases, there is a corresponding increase in the average number of eggs per fish. This would suggest that by selecting the larger individuals, as has been done through four generations, we may have unconsciously increased egg production.

It is not true, however, that every large female will yield a larger number of eggs than a smaller one. Referring again to Table II, it happens that in the largest group, the smallest number of eggs (950) came from one of the largest fish whose length was 13.75 inches while the 2040 eggs were stripped from a female only 13 inches long. Again a female 10.75 inches long in the smallest group yielded 1224 eggs, which is higher than the yield from the largest fish.

This indicates rather clearly that in attempting to increase egg production one should select individuals on the basis of actual egg counts. When this is not practicable, selection of a group of the largest breeders would probably give the highest average yield.

As stated above, the average number of eggs per female was 1164, which is more than four times as many as the ordinary hatchery trout produces at first spawning. There were 28 individuals or 52.8% yielding more than the average number, and 25 less than the average. Of the latter, 15 produced fewer than 1000 eggs and in only 3 was the production below 700.

Several hundred of these breeders were held another year until the second spawning. Of these, 81 females produced a total of 155,199 eggs, an average of 1916 per fish. The two highest yields of 2848 and 3007 came from females each 15.75 inches long. The three largest females were from 16 to 16.5 inches long and gave an average of 2423 eggs each, while the smallest female was 10.75 inches long and produced 854 eggs. This last value is close to, though a little above, the average yield of the ordinary hatchery trout at the second spawning.

Taking the group as a whole, there was an average increase in length during the extra year of about 1.5 inches, but the average increase in egg production was about 752 per female or approximately 64%.

Quality of the Eggs

One of the principal reasons for stripping pairs and isolating the eggs in separate compartments was to facilitate a determination of whatever variation in the mortality might occur among eggs of the various breeders. The losses during incubation had been increasing steadily since the first generation, but it was believed that some individuals might give eggs of better quality than others, and if these could be isolated and the resulting young reared to breeding age in a pond by themselves, the losses during the egg stage might be materially reduced.

Ordinary hatching trays of regular size were divided transversely by wood partitions into compartments each large enough to hold the eggs from one pair. Each compartment was labelled with a number tack for subsequent identification. It was then a simple matter for a hatchery employee to record on a slip of paper under an appropriate number the daily losses in each compartment.

Referring again to Table I, we would call attention to the increase in mortality up to the eyed stage in the second and third generations and a drop during the fourth generation to a point somewhat below that of the first. We are unable to account for this decline unless the mating of pairs may have given a little higher percent of impregnation than was the case in group fertilization. However we do not have sufficient data to prove this point and so advance it merely as a possibility.

In studying the losses in the various compartments we find the widest variation. For example, in the case of 20 lots fertilized on the same date and incubated on two trays placed in the same trough, the losses ranged from 8.5% up to 99%. Another case of 15 lots showed losses from 12% to 98%, and still in a third case of 15 lots the losses ranged from 7% to 90%.

Table III shows the distribution of these losses in the first group.

Attention is called to the first eight lots of eggs. Here we find females above average size of the group giving the highest individual yields which also show the lowest mortality. This correlation of high egg yield with low mortality is not so close in other series and hence it would not be safe to derive any formula for the selection of eggs on this basis.

The only plan which seems feasible at the present time is to first select for high egg yield and from these groups select those showing lowest mortality.

It was not possible to keep all lots of eggs in separate compartments up to the hatching period without interfering seriously with the regular hatchery operations, hence we do not have mortality data beyond the eyed stage except in the case of a few selected groups.

One such group consisted of the first eight lots of eggs recorded in Table III. Up to the eyed stage the mortality was 9.2%; from

TABLE III

LOSSES FROM FERTILIZATION TO EYED STAGE IN 20 LOTS OF BROOK TROUT EGGS, SECOND SPAWNING

Serial No.	Mortality to eyed stage	Length of female inches	Number of eggs	Serial No.	Mortality to eyed stage	Length of female inches	Number of eggs
1	8.5%	13.00	1974	11	20%	10.75	854
2	9.0	13.50	2006	12	25	11.12	1264
3	9.1	13.75	2564	13	28	11.5	1068
4	9.2	12.75	1631	14	32	12.5	1103
5	9.3	12.50	1803	15	45	12.25	1103
6	9.3	13.00	1421	16	47	11.5	854
7	9.5	13.00	1591	17	52	11.25	926
8	9.7	13.50	2130	18	55	11.5	890
9	13.0	13.50	1638	19	65	11.25	1068
10	19.0	13.25	1459	20	99	11.5	926

fertilization to hatching 12% and from fertilization to number 1 fingerlings 19.3%. In another group it was 9.2% to eyed stage; 17.2% to hatching and 26.3% to number 1 fingerlings. A third showed 14.4%, 20.9% and 35.4% respectively for the same periods. All of these groups will be reared in separate ponds to breeding age at which time it will be possible to determine whether these selections will have resulted in a lower average mortality in the next generation.

In closing we may cite two outstanding practical advantages that have resulted from the breeding experiments:—

1. It is now possible to have trout for stocking purposes averaging somewhere between 6 and 7 inches long towards the end of the first summer instead of the usual 3, 4 and 5 inch fingerlings.
2. On account of the increased egg yield it is necessary to keep only about one-fourth the number of breeders as was formerly the case.

Just how great has been the financial gain depends upon two other factors which have not yet been studied. These rapid growing, high yielding fish require a larger amount of food than ordinary trout if one is to take full advantage of their growth possibilities. However it is also a question whether they do not utilize food more efficiently. Should this last be found to compensate to some extent for the increased food requirements, the financial gain might then be very marked.

SOME SUGGESTIONS FOR BREEDING SPECKLED TROUT

JAMES CATT

Superintendent of Fish Culture, New Brunswick

The following paper is submitted to the Association, not with the idea of supplying definite information, but rather as suggesting a field for investigation that should prove interesting, and may be of value.

Observations in regard to wild speckled trout tend so show that a wide range of suitable but diversified habitats exist in the Maritime Provinces. It is therefore probable that conditions classified as optimum should refer to a variety or strain of speckled trout, and not to the species as a whole.

A common conception of the proper environment for speckled trout is the cool, clear stream of not too great a volume containing well shaded pools of some depth and with protective contours of bottom and sides. These conditions, however, are not by any means essential, for we find some of the best speckled trout waters in the Maritimes presenting features almost diametrically the opposite—ponds or small lakes, filled with vegetation, whose bottoms consist almost entirely of mud and whose water is comparatively warm. During the summer some of these ponds nurture an emergent vegetation so dense that clear open stretches of water are confined to areas a few yards square. In others, the plant life is chiefly made up of submerged forms. Provided there is but a limited number of enemy and competitor fishes in each case, these two types of water may present optimum conditions for speckled trout, but not necessarily for a single strain of the species.

Again we find migratory, partially migratory and non migratory strains, those that are sea run or inhabitants of estuaries, those that leave the streams in the spring for cool waters of the deeper lakes during the summer, returning to the streams again in the early fall, those that leave the lakes on their spawning run only, and those of purely lacustrine habit that spawn and may be found at all stages of growth in their native lakes.

Noticeably in the migratory strains there appear to be considerable differences in the ages at which the fishes reach maturity and in their reproductive frequency.

With this wide variety of strains requiring such diversified habitats, it appears probable that it will be found advantageous to stock the several classifications of water with the most suitable—frequently the native—strain or with fishes reared under conditions similar to those that obtain in the water to be stocked.

With this intent the Department of Fisheries has authorized initial experiments at Saint John Hatchery. As at any one plant it is not practical to create a very great variety of conditions, the work at present is being confined to:—

(1) Rearing speckled trout in a spring water pond.
(2) Rearing speckled trout in water of lake origin.
(3) Rearing speckled trout in a mixture of ¼ spring and ¾ lake water.

In each of these cases 200 parents have been selected and retained in ponds under the three different types of conditions. Their first progeny is being held in enclosed spaces in these several brood ponds. These young fishes on reaching maturity will be spawned and the eggs incubated in the same water supply as that which in each case held the parents. The resultant offspring on reaching the fingerling stage will be divided so that each of the three groups will be held for comparison in each of the three ponds. The experiment will be lengthy, as it must be continued through several generations before any definite conclusion of its value may be drawn.

In addition, steps are being taken to determine the age of maturity and the spawning frequency of some migratory sea run strains when held in captivity. To accomplish this, it has been necessary to capture "bright" or non spawning trout on their upstream migration. After their first spawning, the age of these fishes will be determined by scale examination. At present it is believed that these fishes—usually from ½ to ¾ lb. weight—are yearlings. Existing data show that about 25% of the stock spawns in the second fall of captivity. A few have not spawned in their fourth fall.

Discussion

Mr. Rodd: I think Mr. Catt's paper corroborates some of the evidence given by Mr. White this morning. Mr. White believed we have many strains. That assumption is the only way we can explain some of the occurrences in our hatcheries when transfer of stock has been made from one province to another. We are endeavouring to establish strains by selective breeding for the different environments.

Dr. Huntsman: Has Mr. Catt any evidence as to the trout in comparatively warm stagnant ponds being different from those in the clear streams?

Mr. Catt: We have no evidence except that in certain cases a strain developed in one type of water will not give us as good results as a strain developed in another. We are endeavoring to raise trout in a habitat that corresponds to the water to be stocked.

UNPRODUCTIVE WATER AREAS MADE PRODUCTIVE

J. A. Rodd

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The general principles of Fish Cultural work in Canada are the same as they are in other countries, but the details and equipment are necessarily modified to meet varying conditions of climate, water supply and location.

While the question of "Fry vs. Fingerlings" was banned many years ago as a topic of discussion at the Conventions of this Society, —and it is not my desire to attempt to revive it,—the results to which I shall refer were attained by the distribution of free-swimming hatchery reared fry and not by the distribution of fingerlings or older fish. These distributions of fry made previously "barren" areas productive; provided some splendid angling where none previously existed, and extended the angling from the spring or autumn months over the whole of the open water season.

So far as I am aware the relative efficiency of natural reproduction, the planting of eyed eggs and the distribution of fry, fingerlings, yearlings, or older fish has never been definitely and scientifically determined, and many divergent views and opinions are held on this question. While each method, under certain conditions, has something to commend it, the Canadian Department of Fisheries is endeavouring to replace opinions by facts, and an investigation with regard to the sockeye salmon has been going on for several years at Cultus Lake, B. C., under Dr. R. E. Foerster, of the Biological Board of Canada. Natural reproduction, egg-planting and fry distribution have been practised, and unless something unforeseen occurs the first distribution of sockeye fingerlings will be made this year and the first distribution of yearlings will be made in Cultus Lake in 1931.

Quill Lakes:—Big and Little Quill lakes in central Saskatchewan cover an area of approximately 230 square miles. They have no visible outlet and their waters are strongly saline. According to the early settlers, sticklebacks were the only fish present in these lakes twenty years ago.

This central portion of the Prairies is not well supplied with fish, and a local supply is consequently of considerable importance to the residents. After proper examination, whitefish and cisco fry were distributed in 1924 in the creeks that flow into the easterly end of Little Quill Lake where the water is least saline. Some whitefish were caught during the winter of 1925–26, and increasingly larger numbers have been taken during each subsequent season. The whitefish and cisco caught in 1927–28, three years after the first introduction, averaged 2½ and 1¼ lbs. respectively. The catch of cisco last winter

(1929–30) was about eight times as large as that of the previous year. Food conditions are satisfactory and natural reproduction is taking place. So long as present conditions continue a previously "barren" area of 230 square miles of water may be expected to produce an annual crop of food fish of superior quality.

Southwestern Saskatchewan:—Southwestern Saskatchewan is the newest trout district in Canada. No species of trout is indigenous thereto, and to those who are acquainted with its general characteristics and topography, the presence of high class game fish in the streams of the "dry" belt was rather astonishing, since this part of the country is associated with alkali in the soil and a high percentage of alkaline salts in the water.

After examination, experimental plants of brown and Loch Leven trout were made in 1924 in several streams that rise in the Cypress Hills and flow into Cypress Lake. These fish have done extremely well. They have spread from the smaller tributaries to the main streams many miles below the points of distribution. Naturally hatched fry have been observed, and specimens up to 26 inches in length, 13 inches in girth and 5 and 6 lbs. in weight were taken in 1929, only four years after the first introduction.

Similarly, distributions of rainbow trout were made in Battle Creek in 1924, and in Armstrong Creek, Sask., in 1925. Results are equally gratifying. Specimens up to 18½ inches in length and 3½ lbs. in weight were taken in Battle Creek, and 20 inches in length and over 4 lbs. in weight in Armstrong Creek in 1929, viz., 5 and 4 years respectively after the first distributions. The establishment of game fish and the provision of angling, second to none, in a district where trout fishing was previously unknown is the source of considerable gratification and enjoyment to the residents.

Jasper National Park, Alberta.—The most important game fish of this district have their spawning season and are protected by close seasons during the spring months up to June 15th. For the purpose of providing some sport before the season for cutthroat and rainbow opens, the introduction of Eastern speckled trout into the Medicine-Maligne Lake system of the Athabasca river was undertaken. The first distribution was made in 1928 and the second in 1929. The fish have done extremely well in their new environment and were taken readily with spoon and fly all through the system during the summer of 1929. Although the fish at that time were not more than sixteen months old, many specimens were 18 inches in length and would spawn in their second year.

The Medicine-Maligne Lake system was at some early date, before the memory of man, shut off from the Athabasca river by a rock slide (the only outlets are underground) which forms an effective barrier to the ascent of fish from the lower river and was barren of fish life before the speckled trout were introduced. The establishment of speckled trout in Jasper Park not only provides some angling through-

out the whole of the tourist season, but makes a previously barren area productive.

Pisquid Lake, P. E. I., and *Clear Lake, N. B.*—As opposed to the Jasper Park district angling for the native species, the Eastern speckled trout is at its best in the Maritime Provinces during the spring months, but is closed from October 1st each year to March 31st following. For the purpose of extending the angling season rainbow trout, which are at their best in the late summer and early autumn, were introduced into Pisquid Lake, P. E. I., and Clear Lake, N. B., in 1925. Pisquid Lake has a small outlet stream, in which screens have been maintained, and Clear Lake has no visible outlet. The rainbow have done extremely well in both lakes. Many fish of 2, 3 and up to 4 lbs. in weight were caught in Pisquid Lake in 1927, from 2 to 2½ years after the first introduction, and 5 lb. fish were caught in 1929.

The results in Clear Lake are almost equally good. On June 15, 1929, four years after the first introduction, a departmental officer, who was doing some test fishing, took amongst others, on a fly, one 20 inch female of 3 lbs., one 20½ inch male of 3¼ lbs., and one 22 inch female of 4½ lbs., all spent fish.

Before the introduction of the rainbow trout, Pisquid Lake was a depleted speckled trout lake, and Clear Lake contained nothing better than sticklebacks, smelt and suckers. The establishing of rainbow trout in these lakes has extended the angling over all of the open water season whereas it previously ended on September 30th.

Discussion

Mr. Rodd: While I am dealing with the results from fry distribution I do not mean to infer that fry distribution is the most efficient method in all locations. We believe that under certain conditions fry distribution is equally efficient and far less costly than the distribution of older fish.

Mr. Titcomb (Connecticut): The most ardent advocate of fingerlings or yearlings as against fry will acknowledge that in virgin waters the salmonidae produce very satisfactory results when introduced as fry. That fact has been demonstrated throughout the Rocky mountains and the mountainous lakes of the Pacific coast, and in the acclimatization of our American salmonidae in the waters south of the equator and in other parts of the world. Rapid growth always follows the introduction of the salmonidae in virgin waters.

FISH CULTURE IN THE PRAIRIE PROVINCES, AND SOME OF ITS RESULTS

G. E. Butler

Hatchery Superintendent, Winnipegosis, Manitoba

Fish Culture in the Prairie Provinces was inaugurated in the year 1893 with the building of Selkirk Hatchery on the Red River tributary to Lake Winnipeg. Its output for the first season (1894) was 14,500,000 whitefish fry. Since that time the service has increased to seven main hatcheries with several subhatcheries and camps which made a distribution of 435,741,550 eggs and fry during 1929.

The principal work of the Prairie hatcheries has been to replenish the supply of whitefish and *pickerel on the large commercial fishing lakes, although of late years increasing attention has been paid to sport fishing lakes and the propagation of sport fish. To this end trout eggs have been collected, received by transfer or purchased, and the fry planted in suitable small lakes that were barren or without the varieties introduced. Widespread distributions of pickerel fry have been made in many of the small lakes, and fish not indigenous to the Prairie Provinces have been secured by exchanging eyed pickerel or wall eyed pike eggs for bass and crappie fingerlings with the North Dakota Game and Fish Commission.

In Manitoba there is a whitefish and pickerel hatchery on Lake Winnipeg, a whitefish and pickerel hatchery on Lake Winnipegosis and a pickerel or wall eyed pike hatchery on Lake Manitoba. In Saskatchewan there is a hatchery at Fort Qu'Appelle on Upper Fishing Lake producing whitefish, pickerel or wall eyed pike and trout. In Alberta trout hatcheries are operated at Banff and Waterton, and a whitefish and pickerel hatchery at Lesser Slave Lake. These are the main establishments although subsidiary hatcheries and egg collecting stations are also operated.

On Lake Winnipeg and Lake Winnipegosis there are many reports of increased whitefish production attributed to hatchery distributions, but as whitefish and pickerel fry are liberated as soon as they are hatched it is difficult to mark them to prove results. Marking of whitefish fry was, however, attempted in 1928 at Winnipegosis Hatchery by Mr. Alan Mozley of the Biological Board of Canada and over 1,000 fry were marked by cutting off one pectoral fin. It is still too soon to look for re-captures of these marked fish. With the small barren lakes, however, no marking is necessary to prove results, for some remarkable records are on hand from stocking these lakes with hatchery fry, or by transfer of yearling or older fish from other lakes. In 1924 five cans of pickerel fry from Gull Harbour Hatchery on Lake Winnipeg were planted in Goose Lake at Roblin, Manitoba, a barren lake of about 160 acres area, and since then annual plantings have

* In Canada the wall eyed pike is commonly called pickerel.

been made. Since 1927 the citizens of Roblin have enjoyed good pickerel fishing in Goose Lake. Today when one looks into the clear waters of this lake pickerel at all possible ages are seen in schools. Again Lake William, a Manitoba lake in the Turtle Mountain Forest Reserve, that was barren at one time, has become a noted pickerel fishing lake since the introduction of hatchery fry. We now have scores of anglers taking good catches of wall eyed pike or pickerel from this lake, and there is even considerable revenue from the sale of angling permits.

Perhaps the most remarkable result in Prairie Lake fish culture is at Quill Lake, Saskatchewan, a one time barren lake, with very alkaline water unfit for man and beast to drink, and with a very offensive smell. By way of experiment whitefish fry produced from eggs shipped from Winnipegosis to Qu'Appelle Hatchery, together with cisco fry from Ontario eggs also hatched at Qu'Appelle, were planted in the least alkaline of the two Quill Lakes, and to the surprise of everyone the fry not only survived, but actually thrived in the alkaline water, with a rate of growth over 50% faster than whitefish in Lake Winnipeg. The fish have spread to the more alkaline lake and today both Quill Lakes are stocked with whitefish and cisco. Eggs by way of experiment have been taken from Quill Lake whitefish by officers of the Biological Board of Canada, and hatched in the alkaline waters, so it is concluded that Quill Lake fish will be able to reproduce.

Burton Lake, near Humbolt, Saskatchewan, is a pretty little lake of about 100 acres area and is another noteworthy example. This lake had no edible fish in it, but in 1924 one hundred and thirty mature perch were introduced by transfer from a distant lake. Today Burton Lake is actually teeming with perch, and from its waters perch are seined to be transferred in distributing cans by truck to stock other barren lakes within convenient reach. This branch of fish culture has been carried on extensively by the staff of the Qu'Appelle Hatchery and every year many barren lakes are stocked by transfer of yearling or older fish from producing lakes.

In Alberta we have observed the remarkable growth of speckled trout introduced into barren Jasper Park Lakes where these fish have spawned before reaching two years of age. A paper of this nature has to be brief, and the few instances given of the results of fish cultural efforts are only scattered instances of a very small part of our total work which is yearly increasing. Each season more and more barren lakes are being stocked with edible fish, and it is the hope of the writer that some of those at present engaged in this work will live to see the day that every lake in the Prairie Provinces capable of supporting fish life will be stocked with edible fish. Fish Culture has proven to be a profession worthy of one's highest efforts, for it can be most truly said "He has not lived in vain who has made fish grow where none grew before."

A CIRCULAR POND WITH CENTRAL OUTLET FOR REARING FRY AND FINGERLINGS OF THE SALMONIDAE

Eben W. Cobb and J. W. Titcomb

State Board of Fisheries and Game, Connecticut

The circular pond is designed for the purpose of obtaining a uniform current of water throughout its entire area by the use of a comparatively small volume of flow; it also has the advantage of being, to a large extent, self-cleaning. The principle of the circular pond is not a new one. Atkins, one of our most noted pioneer fish culturists and Superintendent of the U. S. Fisheries Station at Craig Brook, Maine, successfully reared many fingerling salmon in half hogsheads, supplied with water from a hose in such a manner as to produce a circular motion.

L. E. Mayhall, Superintendent of Hatcheries in the State of Washington, is probably the first man to design and build the circular central outlet type of ponds. As far back as 1904, Mayhall had constructed three circular ponds, 5 ft. in diameter by 18 inches deep, and used them inside of the hatchery as rearing pools. They proved so successful that he later built 110 of them. He afterwards constructed three of larger size, one 25 ft. in diameter, one 50 ft. in diameter and another 100 ft. in diameter; all of them 3 ft. in depth. While all three sizes proved successful for rearing trout, Mayhall believes the 50 ft. diameter size is the most practical, both from a construction and operating point of view, and he therefore constructed 36 additional rearing pools of the 50 ft. diameter size. Commercial trout breeders will be interested to know that at the time these circular pools were operated, Mr. Mayhall was raising trout for the market.

The pools as planned by Mayhall are supplied with water through a pipe extending across the middle of the pond. This pipe has holes at intervals, so arranged as to spurt from one side of the pipe as far as the central outlet, and from the opposite side of the pipe beyond the central outlet, thus insuring a clockwise current of water in the pond. These Mayhall ponds were first seen by the senior author of this article in 1926 and by the junior author during the meeting of the American Fisheries Society in 1928. As a result of these visits a trial pond, with central outlet, was constructed at the Burlington Hatchery of the Connecticut State Board of Fisheries and Game, which proved so satisfactory that it has been adopted, with certain modifications, for the rearing of fry and fingerlings. It can also be advantageously used for adults.

Instead of using a pipe across the middle of the pond for supplying water, a short inlet pipe is introduced so that the flow from it is nearly parallel with the bank and at water level. Because the circulation

derived from a given volume of flow into the pond depends somewhat upon the velocity of the water at the point of discharge from the supply pipe, it follows that velocity takes the place of volume where the amount of water supply is limited. It is, therefore, desirable to have considerable fall to the supply pipe in order to accelerate the circulation of the water throughout the pond.

The central outlet (Figure 1) is a concrete base into which are set two elbows for outlet pipes; one connecting with a drainage system which takes care of the refuse matter and the other to receive the normal discharge from the pond if it is to be used over again. The standpipe connecting with the drainage system is set at a slightly higher elevation than the one for supplying additional pools.

The current being distributed over the entire pond causes the fish to distribute themselves rather than to gather at the inlet.

All of the filth of the pond gathers around the central outlet screens, from which point it can be siphoned into the drainage ditch. The siphon consists of 1½ inch rubber hose about 8 ft. long. After filling the hose with water, one end is inserted into the drainage pipe and the other is operated at the bottom of the pond around the screens until all of the refuse has been sucked into the drain, without lowering the water of the pond. By the use of a plank-walk from the embankment to this central outlet of the pond, one can operate the siphon without the use of rubber boots, or disturbing the pond bottom.

One of the advantages of this circulating system is the fact that food continually circulates around the pond instead of being washed quickly against the outlet. This is especially desirable when floating food, such as lungs, is used.

There is another advantage to the circular pond in that it is possible to carry a larger number of trout per cubic foot of water than in the long, narrow rearing races commonly used.

It is believed that a pond of elliptical shape may be more economical of space for a series of pools and be equally satisfactory, but it has not yet been determined what proportion of length to width is most satisfactory.

A second stream of water on the opposite side of the original inlet and flowing in the same direction will, of course, create a stronger current. For example: in the use of hand-driven artesian wells for supplying such pools it may be convenient to locate such wells with a view to using two of them to one pond. However, for a pool 46 ft. in diameter we are using one inlet pipe, having a flow of one hundred gallons per minute, with very satisfactory results.

Discussion

Mr. Rowe (Maine): After the water has gone through the pool, do you use it another time?

Mr. Cobb: Yes, the same as with any other pond. But there are two outlets to the pond, one running to a drainage pond. A greater part of the refuse gathers on the

POND WITH CENTRAL OUTLET

46 ft. diam. x 22 in. deep, supplied with 100 gals. per minute of spring and brook water. From this pool 3853 trout weighing 1706 lbs. were harvested after being carried in it from September 1 to April of the following year. The pool in the background is 39 ft. in diam. x 18 in. deep, supplied with 25 gals. water p. m.

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bottom near the outlet than would be the case with the ordinary pond. We make the pipe which takes the refuse from the syphon slightly higher than the outlet which discharges into another pond, so that we do not disturb these pipes in syphoning. The number of trout you could raise would depend to a considerable extent on the quality of the water.

Mr. Titcomb: In the circular pond the fish are all headed in a complete circle from the outside to the center, and equally spaced. You do not get this distribution in your long, narrow raceway. The equal distribution of the trout over the pond probably accounts for the increased carrying capacity.

HEALTH AND GROWTH OF TROUT WITH RELATION TO WOOD PRESERVATIVES USED IN REARING TROUGHS

Guy Lincoln

State Fish Hatchery, Oden, Michigan

Oden State Fish Hatchery is devoted exclusively to the propagation of various species of trout, but by far the greater emphasis is placed upon Brook Trout. During the past season we received, in round numbers, two and one-half million eggs from several commercial hatcheries. These eggs are hatched and the resultant fry are held in hatchery troughs until feeding stations, such as Mr. Westerman, Superintendent of State Fish Hatcheries, described in his report to the Society last year, are ready to receive them. This occurs usually during the month of May. The hatchery is supplied with artesian well water from wells varying in depth from twenty-five to fifty feet. The present supply is ample to take care of two hundred and twenty-five troughs, using approximately seven gallons per minute. There seems to be no limit as to the amount of water which can be secured.

In 1923, Mr. A. T. Stewart, then Superintendent of Hatcheries, suggested that we attempt to use white enamel instead of the conventional tar preparations in painting the inside of rearing troughs. This was started with a few troughs and the attendants would mention, from time to time, that the fish seemed much better in these troughs. More enameled troughs were added and in the season of 1928–1929 a rather superficial experiment indicated that the fish seemed more vigorous in the enameled troughs and that there was an astonishing reduction in losses. As a result of these observations, we decided to conduct a more careful experiment in connection with this problem.

When the fish were placed in the feeding troughs this spring during the month of February, a very careful check was kept on six enameled troughs and six troughs which had been painted with a highly recommended asphaltum product, which the manufacturers advise is made of high grade Gilsonite and china wood oil. Every precaution was taken to have identical fish and uniform controls in each case. Fish from the same sources were placed in water from the same supply, were fed exactly the same food in the same way. An average of twenty thousand fish per trough were used. These troughs were sixteen feet long, twenty-four inches wide and eight inches deep.

From almost the first day, we picked nearly twice as many dead fish from the asphaltum treated troughs as we did from the white enameled ones. The fish from the latter seemed more vigorous, took food better and made a more rapid growth. The fish from the white troughs were noticeably lighter colored and there was an obvious reduction in the number of little slim "pin headed" trout in their case. In fact, the dead removed from the black troughs were very thin and

looked as if they had been too sick to eat sufficient food to maintain life.

The test in the enameled troughs ran as follows:—

6 enameled troughs, approximately 20,000 each.

Losses during	Feb.	Mar.	April	Total	Wgt. per M
6 troughs	2,356	2,045	454	4,855	16 oz.

The test in the asphaltum treated troughs ran as follows:—

6 asphaltum treated troughs, approximately 20,000 each

Losses during	Feb.	Mar.	April	Total	Wgt. per M
6 troughs	3,262	7,188	4,170	14,620	12 oz.

Our interest being aroused during this test, we decided to make another. We had eight troughs in this particular battery, which had been treated with common coal tar. Selecting four of the eight, we painted them with a coat of shellac and three thin coats of white enamel, comparing the results of our test with the other four troughs treated with tar. In this case fish from very late eggs were used which will account for the apparent retarded growth. The results of the experiment were as follows:—

4 enameled troughs, approximately 14,000 each

Losses during	Mar.	Apr.	May	June	Total	Wgt. per M
4 troughs	839	556	625	387	2,407	16 oz.

4 tarred troughs, approximately 14,000 each

Losses during	Mar.	Apr.	May	June	Total	Wgt. per M
4 troughs	1,402	1,132	1,062	941	4,537	14 oz.

Considerable difficulty has been encountered in finding an enamel paint which will adhere permanently to wooden troughs. Several preparations are being tested at the present time, but the matter has not progressed sufficiently to warrant any definite statement. Two porcelain covered metal troughs are being tested at the present time, but these were received too late to enable us to incorporate them in our experiments.

It is not our aim to draw any definite conclusions or make scientific explanations in this case, but rather to present, in a practical way, the facts as we found them.

It is evident, from observations and experiments made at Oden and covering several years' time, that white enameled troughs are vastly superior to those treated with coal tar preparations. Whether or not similar results would follow the use of white enameled troughs under water conditions prevailing at other hatcheries, or whether due to insolubility or color, we are not prepared to say. The results secured at Oden, however, would seem to warrant additional experiments to determine the relative advantages of the manner of treating fish hatchery troughs.

Discussion

Dr. Huntsman: I would like to ask as to the nature of the asphalt treatment and as to whether Mr. Lincoln considers there is any difference in the surfaces of the troughs after these treatments; for example, between asphalt and enamel.

Mr. Lincoln: The asphalt and enamel were laid on the plain wood.

Dr. Huntsman: I make the inquiry because some experiments conducted by Dr. R. H. McGonagle, of the Biological station at St. Andrews, New Brunswick, indicated that asphalt suspended in water was much less toxic than any other material.

Mr. Lincoln: We found that asphalt would rub off and have a rather strong smell after the water covered it, while white enamel would not. The white enamel would crack off a little in a couple of months' time.

Mr. Young (Illinois): Has Mr. Lincoln ever noticed any eye trouble with the use of the enamel?

Mr. Lincoln: We have not had any trouble of that kind.

Mr. Titcomb: I assume that the material was allowed to dry thoroughly and the water run through the troughs for a period before the fry were put in?

Mr. Lincoln: Yes.

THE NUTRITIONAL REQUIREMENTS OF TROUT*

C. M. McCay, John W. Titcomb, Eben W. Cobb, Mary F. Crowell and A. Tunison

Burlington Hatchery of the State Board of Fisheries and Game, Hartford, Conn., and Animal Nutrition Laboratory, Cornell University, Ithaca, N. Y.

Introduction

During the past year we have continued our studies of the nutritional requirements of brook trout along the lines planned at the beginning of our experiments.[1] Our objective has remained unchanged, namely, to develop a cheap feed for brook trout. Such a feed must not only be cheap at the present time but must be made up of materials that are produced in sufficient quantities that any demand made upon the supply for the purpose of feeding fishes is insignificant in relation to the total production of the commercial feed. In other words, we have centered our experiments upon foodstuffs that are used generally for rearing farm animals and the production of our national meat supply.

We have continued to develop our work along two lines. In the first place approximately half of our experiments have been devoted to defining the fundamental nutritional requirements of brook trout in order to bring their feeding within the scope of the modern science of nutrition. Such work is essential since the science of nutrition is young. Many of its hypotheses are weak since they are based largely upon experimental work with one species, the white rat. Such work in defining the fundamental food requirements of a species may seem an unduly slow method of attaining our goal, but every student of the husbandry of animals realizes that such work affords the direct path. Our second line of development has involved a continuation in testing a great variety of commercially available products. After four years of such work we are now in position to assign a definite rating as trout feeds to many of the common feeds used in rearing farm animals.

Two new lines of experimental work have been added during the past year. The first of these is concerned with improved methods for combating fish diseases. The use of ultraviolet radiation for this purpose has been discussed in a separate preliminary report. Our second development is concerned with nutritional studies upon fry immediately after the absorption of the egg sack. Previous feeding trials have been carried out with experimental groups of trout that had already been fed for four or more weeks upon the usual hatchery diet of raw heart or liver. For some time we have appreciated the

*These experiments were financed jointly through grants from the General Foods Corporations represented by Clarence Birdseye of Gloucester, Mass., and from the Conn. State Board of Fisheries and Game. The fish products used in these experiments were furnished by the General Foods Corporation.

advantage of very rapid growth from the earliest feeding, in order to produce the largest possible stock for summer planting. The advantage of a very rapid growth during the earliest stages becomes more apparent when one recalls our previous work in which we have shown that the growth of trout is a logarithmic rate in contrast to the growth of all the warm-blooded mammals reared for man's meat supply.[2]

In our previous reports we have shown that the quantitative protein requirements for trout is very similar to that of other species. Optimum growth requires that the diet include more than ten per cent of its calories in the form of protein. We have shown that starch can be used by trout for a source of energy. It is used to better advantage after cooking than in the raw state. We have made a number of attempts to determine the "mineral" requirements of brook trout. The trout occupies a unique position in being able to thrive upon diets that are rich in phosphorus and poor in calcium. Two of our earlier experiments have shown that an adequate supply of calcium is desirable if not essential. In the first place haddock residues that contained the bones of sea fish ground up with the meat were superior for growth and the maintenance of life to haddock flesh alone. In the second place all our experiments in which dry skim milk has been used as a supplement to raw meat have shown a superior growth to that obtained upon raw meat alone. Both of these experiments indicate a need for calcium, but the final solution to this problem must await further work with purified diets. During the past year we have carried out a considerable number of analyses for calcium and phosphorus upon the bodies of trout fed varying amounts of calcium. These data will be reported separately at a later date.

A number of our earlier experiments have been concerned with the vitamin requirements of brook trout. Some evidence indicates there is a need for some of the recognized vitamins, but most experimental evidence is obscured by the requirement for some substance in raw meat which we have termed "factor H." Until this is isolated and partly identified, little progress can be made in studying the vitamin requirements of brook trout.

In our past feeding trials we have given some attention to the feeding of cellulose products. Under natural conditions the trout consumes a large amount of inert material that is excreted after passing through its digestive tract unaltered. Since these inert materials such as bran or cellulose play a rather important role in the prevention of intestinal troubles in man, such as constipation, we have considered them in their possible bearing upon the health of hatchery fed trout. In our earlier work we have shown that the trout is able to consume large amounts of inert cellulose materials without any detrimental effect to its growth.

All our experiments employed the same technique of feeding and weighing the trout as that described in our previous reports.[3]

Experimental

Feeding Trials with Varying Amounts of Protein and Vitamin Supplements

Since all our earlier experiments upon the protein requirements of brook trout were carried out with vitamin supplements fed at levels which had been found to be adequate for the rat, and since trout upon such diets always failed, we designed a new series shown in Table 1. Commercial casein was used. The starch was boiled and dried before being fed. The salt mixture was made up of equal parts of bone meal, sodium chloride and calcium carbonate. Yeast was the dried, rat-tested product from the Northwestern Yeast Co. We have not employed highly purified casein or salt mixture, because our previous studies in which such diets have been employed have always resulted in failure. These failures can only be interpreted in terms of dietary deficiencies or toxic contaminations. We are convinced that the failure has always been the result of a deficiency, since a raw meat supplement to such diets produces normal growth and length of life in brook trout. If the ingredients such as casein were toxic for this species the reverse outcome would be expected. Further purification of a product is futile if it is already deficient in the limiting factor under consideration. From Table 1 the following characteristics of the various diets will be observed:—

TABLE 1

Diet No.	Casein	Dextrin	Cooked Starch	Salt Mixture	Cod Liver Oil	Yeast	Lard
A-1	5	40	41	4	5	5	
A-2	10	38.0	38.0	4	5	5	
A-3	11.5	39.0	40.0	4	5	0.5	
*A-4	25.0	30.0	31.0	4	5	5	
A-5	40.0	23.0	23.0	4	5	5	
A-6	40.0	15.0	16.0	4	5	20.0	
A-7	40.0		1.0	4	5	50.0	
A-8	40.0	25.0	26.0	4	5		
A-9	40.0	23.0	23.0	4		5	5
A-10	40.0	25.0	25.0		5	5	

*Received orange juice.

Number	Characteristic	Result
A-1	Very low protein	No growth
A-2	Low protein	Slight growth
A-3	Low protein—low yeast	No growth and early death
A-4	Medium protein	Moderate growth
A-5	High protein	Moderate growth
A-6	High protein—high yeast	Good growth
A-7	High protein—very high yeast	Good growth
A-8	High protein, no yeast	Moderate growth, early failure
A-9	High protein, no cod liver oil	Moderate growth, early failure
A-10	High protein, no salt mixture	Moderate growth

In chart 1 we have shown the growth and mortality curves upon these various diets. Although this experiment is not completed, the mortality curves show that all groups are beginning to die. These data permit us to draw the following conclusions:—

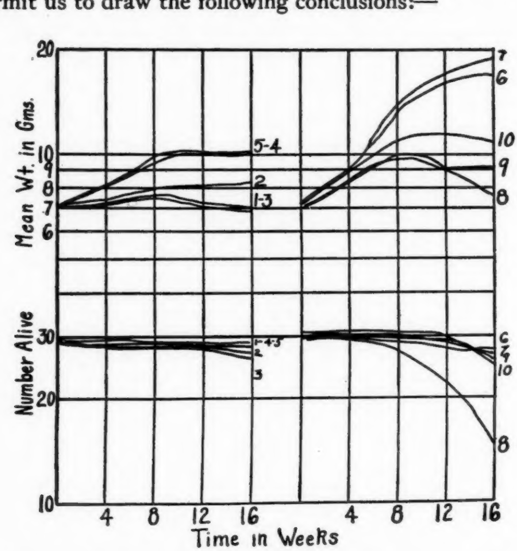

Chart 1. Growth and mortality curves upon diets with varying amounts of protein and vitamin supplements. Diet Nos. 1, 2 and 3 are very low in protein. Nos. 3 and 8 are very poor in yeast. Nos. 6 and 7 are very rich in yeast. No. 9 contained no cod liver oil.

A ten per cent protein intake is inadequate for optimum growth of brook trout even when fed with relatively large amounts of yeast and cod liver oil.

Diets number A 8 and A 9 show that both yeast and cod liver oil when fed at high levels have a slight influence upon the growth of brook trout. This contrasts with our earlier work in which we fed vitamin supplements at levels satisfactory for the rat. These results do not justify the use of either yeast or cod liver oil by the fish culturist in any of his practical diets. These experiments further confirm our hypothesis of a thermolabile factor in raw meats, factor H, which is the most important for the growth and maintenance of life in brook trout. This factor may have been present originally in yeast and have been destroyed in the drying process, as suggested by Dr. Tressler. No significant differences were shown between diets A 10 and A 5. No. A 10 grew slightly more rapidly and failed a little

earlier. This merely indicates that in these experiments other limiting factors came into play much more quickly than the inorganic element deficiency. Since we had previously shown that dextrin and starch can be interchanged in the diet of the trout, we have employed varying amounts of dextrin in the amounts needed in order to obtain the proper physical composition for each diet.

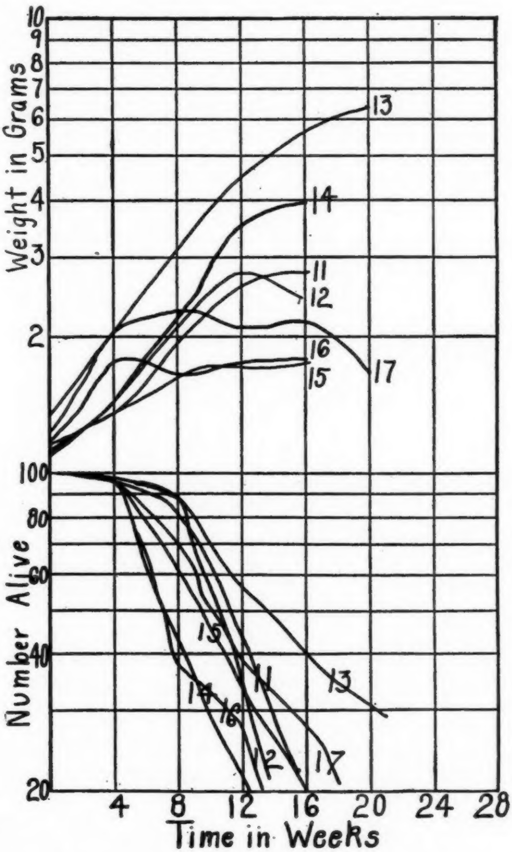

Chart 2. Growth and mortality curves of trout fed diets containing varying amounts of cottonseed meal, fish meal, dry skim milk and alfalfa. Diet 13 was made up of about equal parts of fish meal, dry skim milk and cottonseed meal.

The Use of Fish Meal, Cottonseed Meal, Dry Skim Milk and Alfalfa Meal in Trout Feeding

In preceding experiments (3) we have shown that fish meal, cottonseed meal and dry skim milk are excellent trout feeds when properly supplemented. We have never been able to use them alone for more than a few months in one period. Properly supplemented with raw meat they can be used for long periods, probably as long as raw meat alone.

In table 2 we have shown diets A 11 to A 17. Nos. A 11 and A 12 were designed to determine if cod liver oil, a rich source of vitamins A and D, might not be a satisfactory supplement for dry skim milk and cottonseed meal. Chart 2 shows the growth and mortality curves upon these diets. Since both groups 11 and 12 grew slowly and died early, cod liver oil must be ruled out for supplying the deficiency in these rations and we must revert to our hypothesis of factor H. Diet

TABLE 2

Diet No.	Cotton-seed Meal	Dry Skim Milk	Fish Meal No. 2	Yeast	Cod Liver Oil	Cooked Starch	Dextrin	Alfalfa
A-11	25	33		10		16	16	
A-12	25	33		10	5	12	15	
A-13	33	33	34					
A-14		33	25			18	19	5
A-15	33		34				18	15
A-16	33		34		5		23	5
A-17	33		34	5	5		23	

Fish Meal No. 2—Special vacuum dried low temperature haddock meal.

13 was made up of equal proportions of fish meal, cottonseed meal and dry skim milk. This diet yielded excellent growth for a period of 12–16 weeks but finally failed. This is probably the most satisfactory mixture of commercial dry feeds that we have evolved thus far. During the coming year we expect to test it on large scale experiments with a satisfactory supplement as a source of factor H. In diet A 17 the dry skim milk was omitted from this mixture. Early failure and slight growth resulted. Since alfalfa is known to be rich in protein, calcium and vitamins A and B, we have employed it as a supplement in experiments A 14, A 15 and A 16. It was mixed with the diet in the form of meal. Even in this form it is difficult to get a suitable mechanical mixture. All diets containing alfalfa meals were failures. No. A 16 failed sooner than No. A 17 which contained cod liver oil. The difference between these two diets is not significant. We have no explanation for the superiority of diet A 13 over such diets as A 11, A 12 or A 17. Except A 11 all these diets should contain adequate amounts of all recognized essential nutrients.

One other plant product has been tested during the past year. This is known commercially as hominy feed and has proved about equal to such products as red dog flour.

The Limit of Toleration for Cottonseed Meal and the Use of Preserved Raw Meat As a Supplement

In the course of a series of experiments in feeding various forms of beef liver to white rats it was found that raw liver could be held for

TABLE 3

Diet No.	Alcoholized Spleen	Fish Meal No. 2	Cottonseed Meal	Dry Skim Milk	Salt Mixt.	Yeast	Cod Liver Oil	Alfalfa Meal	Dextrin
A-21	30		25		3		2		40
A-22	25	25	20	25				5	
A-23	25		45	25				5	
A-24		25	45	25				5	
A-25			70	25				5	

a year in a refrigerator at 5-6° C. if the liver were ground up with the addition of about one-tenth of its weight of alcohol (95%). We designed the diets shown in table 3 to answer three questions:—

1. Is beef spleen a satisfactory supplement for a mixture of cottonseed meal, dry skim milk and fish meal?

2. Can preserved raw meat provide a satisfactory source of factor H?

3. How much cottonseed meal can brook trout be fed without injuring them?

The answer to these questions is shown in the growth and mortality curves of chart 3. Of the diets supplemented by preserved raw spleen, Nos. A 21, A 22 and A 23, all have shown good results in both growth and low mortality rates. Since a small amount of alfalfa meal was incorporated in each of these diets it shows it has no detrimental influence although we have not shown any positive value. We can conclude from these experiments that raw meat retains its potency when preserved with alcohol. Raw spleen is moderately satisfactory as a supplement for a mixture of cottonseed meal, fish meal and dry skim milk. Diets A 23, A 24 and A 25 contain relatively large amounts of cottonseed meal. A 24 and A 25 were used without a raw meat supplement. A 25 failed to grow and started to die quite early in the experiment. The curves show a picture quite similar to that for fasting trout which we published previously (2). The results upon diet A 24 are very similar to those shown by group A 13 in chart 2. This is what one might expect from the similarity in composition of the two diets if our testing technique is accurate.

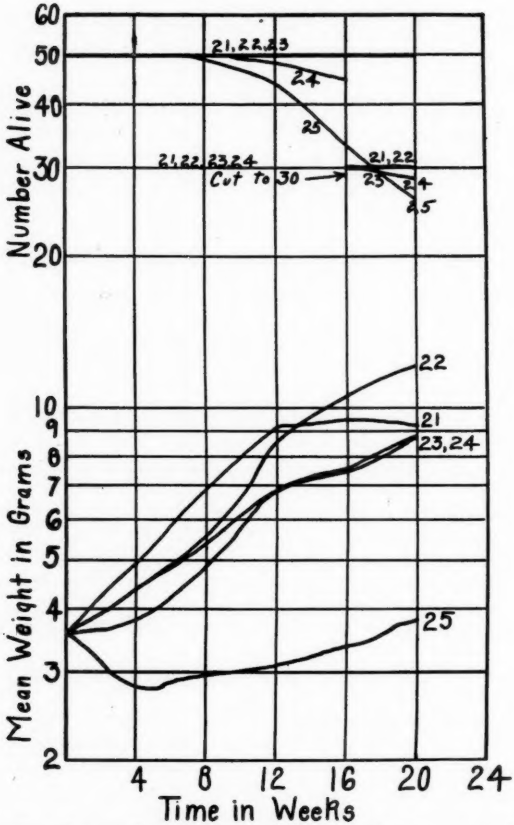

Chart 3. Growth upon diets designed to show the maximum amount of cottonseed meal the trout can tolerate. Diet 25 contained seventy per cent cottonseed meal. This is too much. Groups 21, 22 and 23 were fed diets supplemented with raw spleen preserved with alcohol.

Experiments A 23 and A 24 show that cottonseed meal is non-injurious at a forty-five per cent level. Although seventy per cent is too high, there is no evidence in experiment A 25 that there is any toxic action. Trout appear to be unaffected by the toxic properties that cottonseed meal exhibits when used as a feed for some farm animals. The superior results obtained upon A 22 strengthen our thesis that a mixture of dry skim milk, cottonseed meal and fish meal is superior to any two of the ingredients used alone.

The Use of Dry Skim Milk for Supplementing the Diet of Fry Immediately After the Absorption of the Egg Sack

Although we have had no means which permits us to make a satisfactory measurement of the growth rate of very young trout immediately after the absorption of the egg sack, we believe we are justified in concluding that we have a method for measuring the effect of a given dietary regime during this early stage. Four hundred fry were selected at random just before the first feeding and divided into two groups, Nos. 88 and 89. These were fed the two different diets shown in table 4. Number 88 was reared upon beef liver alone,

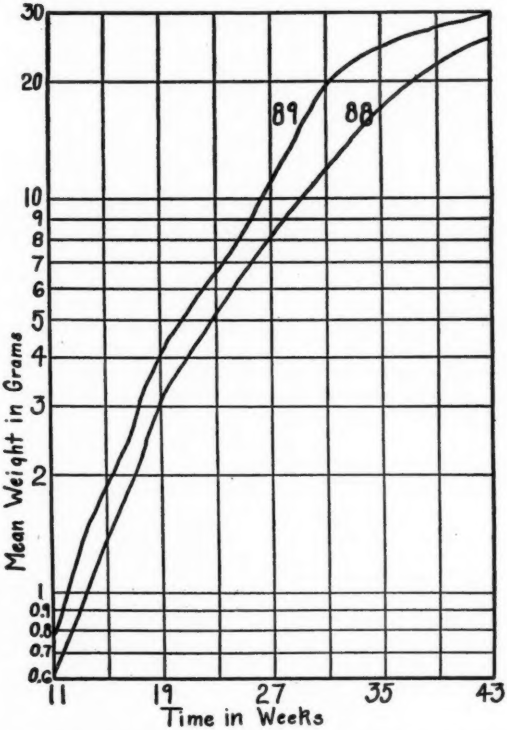

Chart 4. Growth curves for brook trout fed special diets from the time of absorption of the egg sack. No. 89 received a milk-liver diet while No. 88 was fed liver alone. The growth curves are only shown from the time of the first weighing, which was eleven weeks after the first feeding.

while No. 89 received the mixture of dry skim milk, liver, cod liver oil and yeast. From our earlier experiments we have no reason to believe that cod liver oil and yeast made any contribution to the effectiveness of No. 89. These groups were large enough to weigh the first of May. The growth curves are plotted from that date. We believe they are a true reflection of the diets used from the time of the first food that was eaten.

While this experiment shows a slight superiority of the milk fed group, we believe it has a still greater interest in providing a worthwhile method of studying the value of various feeding substances during this early period.

TABLE 4

Diet No.	Beef Liver	Dry Skim Milk	Yeast	Cod Liver Oil
88	100			
89	59	35	3	3

Effect on Growth of Limited Number of Feedings

To determine the frequency of feedings necessary to produce an optimum growth rate for yearling trout, two experiments on a comparative basis were planned. Both groups received the same diet—raw spleen 50 grams, dry skim milk 25 grams, peanut meal 25 grams. The first group (No. 67) received all the food they wanted twice a day every day. The second group (No. 67a) received all the food they wanted two days a week. The growth rate of No. 67 was slightly better than that of No. 67a but the trout in both groups appeared well-shaped and well-nourished.

TABLE 5

Diet No.	Average Weight January 3, 1930	Average Weight March 28, 1930	Total Increase in weight
67	31.0	45.0	14.0
67a	25.5	37.0	11.5

However, the resistance of No. 67a to furunculosis was much greater than that of No. 67.

The Toxicity of Boiled Versus Unboiled Linseed Meal

In a previous report (3) we have reviewed the experiments of Brioux and Richart (4) who have claimed that the toxicity of linseed meal for calves is removed by boiling. We have completed a new

series of experiments to determine whether boiling will detoxicate linseed meal for brook trout. A mixture was made up consisting of raw liver 30 grams, salt mixture 3, dextrin 40 and cod liver oil 2. To this was added in one case 25 grams of dry linseed meal and in another case the same amount of linseed meal which had been previously dropped into boiling water and boiled 2-3 minutes. Boiling did not alter the toxicity of the linseed meal. This experiment casts some doubt upon the theory of linseed meal toxicity. The most generally accepted theory assumes that the toxicity results from hydrocyanic acid which is set free by an enzyme in the digestive tract of the animal. This enzyme is supposed to be present in the original linseed meal. Boiling should destroy the enzyme and prevent the later production of hydrogen cyanide as the meal is digested. We question this theory. The value of linseed meal as a conditioning agent for livestock is usually assumed to be due to its content of oleic acid. For several hundred years animal husbandrymen have employed traces of such toxic agents as arsenic to condition their livestock. It is quite possible that the value of linseed meal is due to the very toxic agent which is fatal for trout. The trout affords an excellent experimental animal for studying this problem since it responds so readily to the toxic agent. The solution of this problem is of interest to agriculture since linseed meal commands a price premium that is questionable on the ground of its digestible nutrients.

The Effect of Roughage Upon the Growth of Trout

In our previous study upon the relation of the cellulose of the diet to the growth and mortality, we employed a maximum of twenty per cent cellophane. (3) This produced little effect upon the growth of trout. We had already found, however, that even ten per cent in the diet of the rat tends to retard the growth rate but does not prevent the attainment of adult size. (5) As far as we have been able to determine it does not shorten the life of the rat since several animals were carried into the third year of their life after consuming about five times their body weight of cellophane.

Since there must be some upper limit at which an inert material will interfere with the growth of even a fish, we have designed new experiments to find this limit. The diets shown in table 6 contained varying amounts of roughage in the form of cellophane. Number 79 contained the most with 35 grams in each hundred grams of feed. This is somewhat more than 35 per cent since the liver is included in the fresh condition. The growth and mortality curves for these various groups are shown in chart 5. No. 79 showed little growth and the growth of No. 78 was impaired. This shows that the optimum amount of inert material is somewhat less than twenty grams of cellophane per hundred grams of feed. On a dry basis this is approximately twenty-four per cent. This value is well above the crude fiber content of most natural trout feeds according to the summary

of Embody and Gordon. (6) This is probably questionable as a factor causing the slower growth of trout under natural conditions.

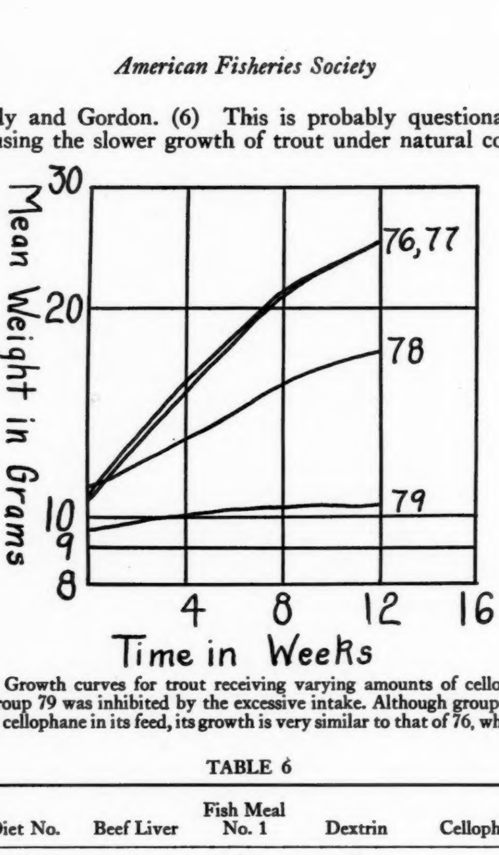

Chart 5. Growth curves for trout receiving varying amounts of cellophane. The growth of group 79 was inhibited by the excessive intake. Although group 77 received five per cent cellophane in its feed, its growth is very similar to that of 76, which received none.

TABLE 6

Diet No.	Beef Liver	Fish Meal No. 1	Dextrin	Cellophane
76	21	29	50	
77	21	29	45	5
78	21	29	30	20
79	21	29	15	35

Fish Meal No. 1—Commercial White Fish Meal.

Summary

A new series of experiments using large amounts of vitamin supplements such as yeast and cod liver oil confirms our earlier conclusions that trout require a protein minimum of approximately ten per cent for normal growth. Very high levels of dried yeast increase the growth rate and period of growth for brook trout but even these high levels do not permit them to live and grow normally. This strengthens our earlier hypothesis that trout are dependent upon a

thermolabile substance for the maintenance of life. These later developments with yeast and cod liver oil do not warrant their use in practical feeding in the hatchery.

Additional experiments have confirmed our earlier findings that fish meal, cottonseed meal and dry skim milk are all satisfactory trout feeds if supplemented with raw meat. A combination of these three feeds affords the best dry product for rearing trout that we have discovered thus far but must be supplemented with raw meat. Our experimental data do not justify the use of ground alfalfa in dry trout feeds.

Cottonseed meal does not seem toxic for trout even at very high levels. Trout refuse to grow and seem to starve to death when as much as seventy per cent of cottonseed meal is used in the diet. Forty-five per cent levels gave good results.

Preserved raw meat is satisfactory as a source of factor H. We have used ground spleen "pickled" in ten per cent alcohol. This keeps for long periods in the refrigerator. We hope to discover more satisfactory preservatives, however, since alcohol is not readily available and some culturists might consider it a needless waste.

Two feeding trials which started immediately after the absorption of the egg sack have been carried out with trout. These have shown that dry skim milk supplemented with raw meat can be used for feeding in the earliest stages to good advantage. Random selection of experimental trout immediately after the absorption of the egg sack and weighing after they have grown to a considerable size provides a technique of measuring dietary values during this period.

New experiments with linseed meal show that it remains very toxic to brook trout even after it is boiled to destroy enzymes. These data cast some doubt upon current theories of the toxic agent contained in linseed meal. They show the trout to be an excellent test animal since it responds very quickly to the poison.

Additional growth experiments to define the toleration limits for such inert materials in the diet as cellulose show that the growth rate of trout decreases at levels that equal or exceed twenty-five per cent. Since this value is considerably higher than the inert material found in most natural foods we do not believe this affords an explanation of the slower growth rates of trout in streams than in the hatchery.

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INVESTIGATIONS ON THE NUTRITION OF SPECKLED TROUT

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Preliminary Report

Introduction

This report is an account of the nutritional investigations being carried on at the present time by the Ontario Department of Game and Fisheries. The results that are recorded herein must be considered as preliminary, since the actual experimental feeding of the trout has been in progress for a period of only twenty-four days.

Detwiler[1] (1930) in his report "Investigations on the Nutrition of Speckled Trout 1" has dealt with the observations noted on fresh meat diets. In connection with the feeding of synthetic diets, with which this paper is concerned, two lines of attack have been adopted, namely,—

1. The effect of feeding liver which has been fractionated by the use of solvents and residues.
2. The effect of variations of the proteins and protein content of the diets.

This investigation was carried out at the Provincial Fish Hatchery, Mount Pleasant, Ontario, and was performed in consultation and co-operation with Mr. H. H. MacKay, Director, Fish Culture Branch, Ontario Department of Game and Fisheries.

Experimental Methods

Fractionation of Liver. Three solvents, ether, alcohol and acetone, were employed in an effort to isolate the beneficial nutritional property or properties of fresh liver. In each case 2 kgm. of fresh liver mush were well shaken with 2.5 litres of the solvent and allowed to stand over night. The residue was filtered, washed with a further 500 c. c. of the solvent, and drained at the pump, and then dried in an incubator at a temperature of 37.5°C, while spread in thin layers on filter paper. The extract was concentrated in vacuo, again at a temperature of 37.5°C.

Dried whole liver was prepared by spreading the mush on porcelain plates and drying at 30°C.

In no case was a temperature in excess of body temperature employed.

The yields are recorded in Table 1.

Basal Diet and Preparation of Liver Diets: A basal diet consisting of casein, starch, and mineral salts was chosen from a consideration of the work of McCay, Bing and Dilley[2] (1927), in such proportions

TABLE I

Solvent	*Extract* (Wet Weight)	*Residue* (Dry Weight)
Ether	40	527
Alcohol	64	578
Acetone	49	603

as to give maintenance but poor growth. The diet was prepared by mixing thoroughly the given constituents in the dry form. To eliminate a possible error due to any supply of Factor H in the casein, which was a technical variety, the latter was heated at a temperature of 150°C for a period of two hours before being prepared in the diet.

The mineral salt mixture employed in all diets consisted of the following mixed in dry form:

Calcium Carbonate	–25%
Bone Meal	–30%
Sodium Chloride	–25%
Magnesium Carbonate	– 5%
Dipotassium Phosphate	–15%
Potassium Iodide	–trace

Ten grams of the extract and 24.0 g. of the residue were added to 100 g. of the basal diet, as recorded in Table II. In the case of the extracts, enough water was added to make a stiff paste with the basal diet, the whole well kneaded, dried at 37.5°C in an oven, and ground in a mortar. The residues were first ground, and then mixed in the dry form.

TABLE II

LIVER FRACTIONATION DIETS

Diets 1 and 2		*Diet 3*		*Diet 4*	
Casein	25	Basal	100	Basal	100
Starch	70	Ether Extra.	10	Alcohol Extr.	10
Min. Salts	5				
Diet 5		*Diet 6*		*Diet 7*	
Basal	100	Basal	100	Basal	100
Alc. Res.	24	Alc. Res.	24	Acetone Extr.	10
		Alc. Extr.	10		
Diet 8		*Diet 9*		*Diet 10*	
Basal	100	Basal	100	Basal	80
Acet. Res.	24	Acet. Res.	24	Raw Liver	20
		Acet. Extr.	10		
Diet 11		*Diet 12*			
Basal	80	Fresh Liver			
Dried Liver	20				

Protein Diets: The ingredients were mixed in the dry uncooked state, in the proportions indicated in Table III. Before preparation, the proteins used were heated for two hours at 150°C to destroy any Factor H content.

TABLE III

PROTEIN DIETS

Diet 13		*Diet 14*		*Diet 15*	
Casein	25	Casein	25	Casein	25
Starch	55	Starch	55	Starch	40
Min. Salts	5	Min. Salts	5	Min. Salts	5
Gelatin	15	Egg Albumin	15	Egg Albumin	15
				Gelatin	15
Diet 16		*Diet 17*		*Diet 18*	
Starch	70	Starch	70	Starch	55
Min. Salts	5	Min. Salts	5	Min. Salts	5
Egg Albumin	25	Gelatin	25	Egg Albumin	25
				Gelatin	15
Diet 19					
Fasting					

Feeding Methods: Ten fingerlings were chosen for each experimental group. The fish were confined in separate screened galvanized iron tanks, the interiors of which were coated with paraffin varnish. Each small trough was 6″ wide x 30″ long, with a water depth maintained at 6″, and supplied with a separate water intake tap fed from a common head trough.

The diets were prepared at the time of feeding by mixing into a stiff paste with water. The fish were fed four times daily, and the troughs cleaned each day.

Results

The results expressed in terms of the average weight per fish in grams are recorded in Table IV.

TABLE IV

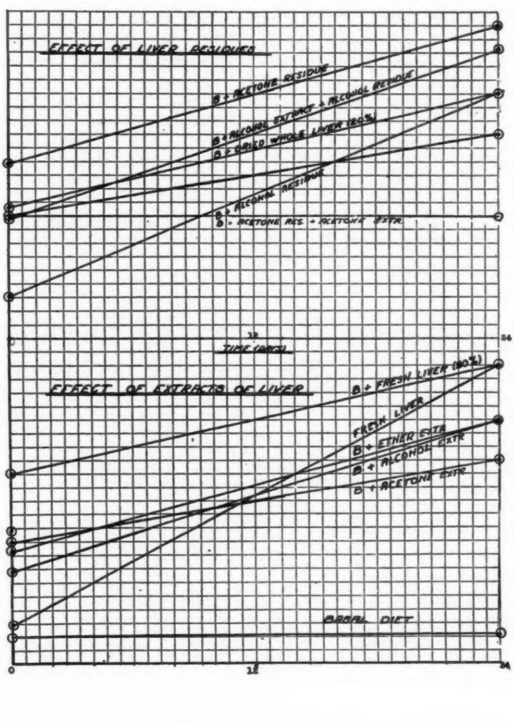
GROWTH OF FISH

Time (Days)	0	24
Diet No.	*Weight per Fish (Grams)*	
1	3.10	3.20
2	3.39	3.30
3	3.52	4.00
4	3.44	4.00
5	3.25	4.00
6	3.54	4.17
7	3.55	3.85
8	3.74	4.25
9	3.55	3.55
10	3.80	4.20
11	3.58	4.00
12	3.24	4.20
13	3.94	4.40
14	3.91	4.40
15	3.49	3.75
16	3.62	3.35
17	3.81	3.30
18	3.33	3.00
19	3.55	3.35

The liver fractionation growth curves are illustrated on Graph No. 1, and the protein diet growth curves on Graph No. 2.

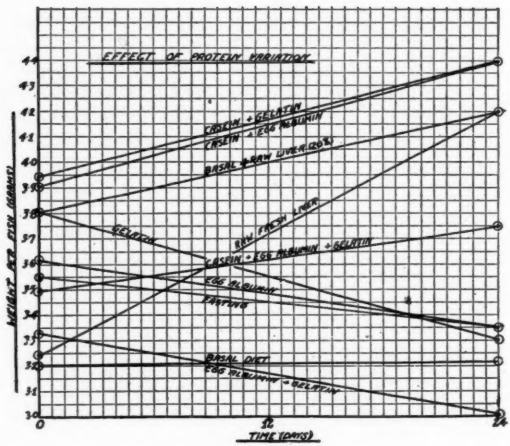
McCay, Dilley and Crowell[3] (1928) have attempted to activate a similar basal diet with extracts of liver, but have observed negative results. They have concluded that Factor H, the agent believed to be the most active in stimulating the growth of trout, was not extracted by alcohol or ether. In view of the fact that McCay and Dilley[4] (1927) showed this factor to be thermolabile, it was considered advisable to repeat the use of these solvents in the fractionation of liver and adhere more rigidly to temperature conditions. McCay, Dilley and Crowell[3] (1928) employed a maximum temperature of 65°C in the concentration of the extracts. No records were given in regard to the effect produced by feeding the residues of the liver. The extract and residue preparations used in this instance were not subjected to a temperature in excess of that of the body, i. e. 37.5°C.

From a consideration of Graph No. 1, it is at once obvious that the



basal diet when supplemented either by extracts or residues of liver gave as good growth as when supplemented by raw liver itself. In view of the short time of feeding, however, these observations cannot as yet be accepted as conclusive.

The basal diet itself shows no growth. When supplemented by gelatin, egg albumin, or both, good growth was obtained as shown on Graph No. 2. The activation again compares favourably with that produced by raw liver, and in this case can only be due to the protein.



Casein is a biologically complete protein, that is, it contains all the amino acids essential for the maintenance and growth of mammals. The amino acid glycocoll, however, is present in traces only. This amino acid is not essential in mammalian nutrition because it can be synthesized in the body as shown by the excretion of acid on a benzoic acid diet free of glycocoll. Gelatin, containing a high content of glycocoll, when employed as a supplement to casein increases the growth rate, which would indicate that the amino acid glycocoll is not synthesized by the fish.

Cystine is present in casein in slight traces only. This amino acid is necessary for the growth, but not the maintenance, of mammals. On supplementing the supply of cystine in casein with a further supply in egg albumin, another increase in growth rate is observed, suggesting the importance of cystine as a growth factor of trout.

Further observations on these trout will be published in a later paper.

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FEEDING EXPERIMENTS WITH BROOK TROUT FINGERLINGS

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The Biological and Fish Culture Branch of the Department of Game and Fisheries of Ontario has for some time been anxious to check up on the relative values of the different kinds of food fed in its hatcheries and also to experiment with other foods with a view to obtaining a more economical diet than that in general use.

To this end a small beginning was made by the writer in the latter part of the summer of 1929 at the Provincial Hatchery at Mount Pleasant, Ontario, but as the time at his disposal did not permit the experiments to be carried on for more than one month, the actual results were scarcely as important as the experience gained in preparation for further work.

During the summer of 1930, ten troughs 17 ft. 8 in. long by 16.5 in. wide and 8 in. deep (inside measurements) were set aside for this work. As these troughs were much longer than required they were divided in half by cross partitions, thus providing twenty good-sized troughs. Each of these divisions was provided with an independent supply of water from the common head-trough and also an independent drain-pipe. The water was kept at a depth of 6 inches and the faucets so adjusted as to permit a flow of water of about four litres per minute. The troughs were covered with wire screens, thus preventing the fish from jumping out. Fifty fishes were put into each trough and when the work was completed every fish was accounted for.

The water to the hatchery is supplied by a small stream which flows into the rear of the grounds. An analysis made during the month of August was as follows:

pH colorimetric	7.8
Dissolved oxygen c.c. per litre	6.2
Free carbon dioxide	4.0
Methyl Orange alkalinity as $CaCO_3$	203.4
Phenolphthalein alkalinity as $CaCO_3$	0.0

The temperature of the water is, as one might expect, considerably influenced by the daily fluctuations of that of the air. The extent of this may be shown by a brief discussion of temperatures taken during the summer. On July 28, for example, the temperature of the water rose from 12.5°C. (54.5°F.) at 7:30 in the morning to 19.0°C. (66.2°F.), the highest temperature recorded during the summer, at 4:30 in the afternoon, a difference of 11.7°F. This was somewhat extreme as may be seen from the mean morning and afternoon temperatures from July 28 to August 28 inclusive. The mean morning temperature, between 7 and 8 o'clock, was 11.5°C. (52.07°F.) and the mean after-

noon temperature, between 4 and 5 o'clock, 15.93°C. (60.67°F.). This shows a daily mean fluctuation of 8.6°F. for this period.

From the nature of the water supply a certain amount of natural food necessarily finds its way into the troughs. This was checked up to some extent in August when the water supplied to one of the troughs was passed through a strainer for a period of 72 hours. During this time about 2.5 cc. of material was collected of which about 50% consisted of fish food and this chiefly as immature aquatic insects.

The fishes used in these experiments were hatched during the latter part of February, 1930, from eggs obtained from the Normandale Trout Ponds, near Normandale, Ontario. They were thus about four and one-half months old. In selecting the fishes it was thought wise to reject both the largest and the smallest, consequently those varying from 1.25 to 1.50 cm. in length were chosen. The selection was rather speedily accomplished by means of a small brass-wire scoop threaded with grocers' cord into one-inch squares. With this, one can often get the approximate length of the fish while in the act of dipping it out of the water. Fifty fishes for each trough were thus selected and weighed. A uniform method of weighing was employed throughout in these experiments.

Feeding experiments were begun on July 10, and the foods experimented with were: beef liver, beef heart, horse meat, dry skim milk, clam meal, beef melt, and tripe (cooked). The diets and troughs involved were as follows:

Troughs No. 1 and 11	Beef liver
Troughs No. 2 and 3	Beef heart
Troughs No. 4 and 5	Beef liver + beef heart 50:50
Troughs No. 6 and 7	Horse meat
Troughs No. 8 and 9	Beef liver + dry skim milk 80:20
Troughs No. 10 and 20	Beef liver + clam meal 50:50
Troughs No. 12 and 13	Horse meat + clam meal 50:50
Troughs No. 14 and 15	Horse meat + clam meal + dry skim milk 60:20:20
Troughs No. 16 and 17	Beef melt
Troughs No. 18 and 19	Cooked tripe

The ratios in the above diets are given in the order in which the constituent parts are named. Before the clam meal was weighed out and mixed with its constituents it was soaked in water in the ratio of one part by weight of the meal to two parts by weight of water. The dry skim milk was weighed and added in the dry condition. It will be noticed that the troughs were run in duplicate. As beef liver is generally accepted as one of the most satisfactory foods for trout of this age it was taken as a standard, or check. The diets were prepared and weighed out three times per week and kept on ice in a specially built ice-box. In the grinding of the meats the finest perforated plate was used. Enamel-ware mugs were found to be very satisfactory receptacles in which to keep the different diets. They were numbered by fastening marked metal labels on the handles.

The fishes were fed at intervals of three hours, and thus, by beginning at 7:30 o'clock in the morning, five feedings were conveniently accomplished. The amount of food fed will be referred to in the general discussion.

On account of the delay experienced in obtaining certain foods a number of the feeding experiments were not begun until several days after July 10. The experiments with melt and tripe were, as a matter

CHART I

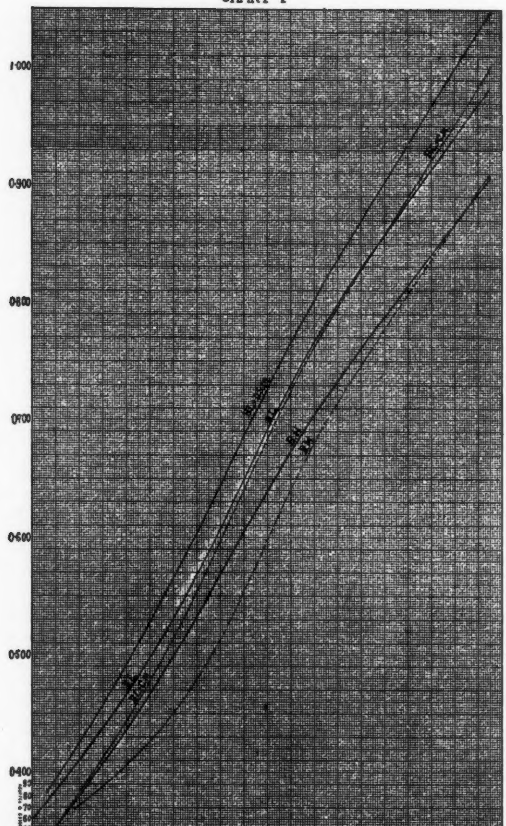
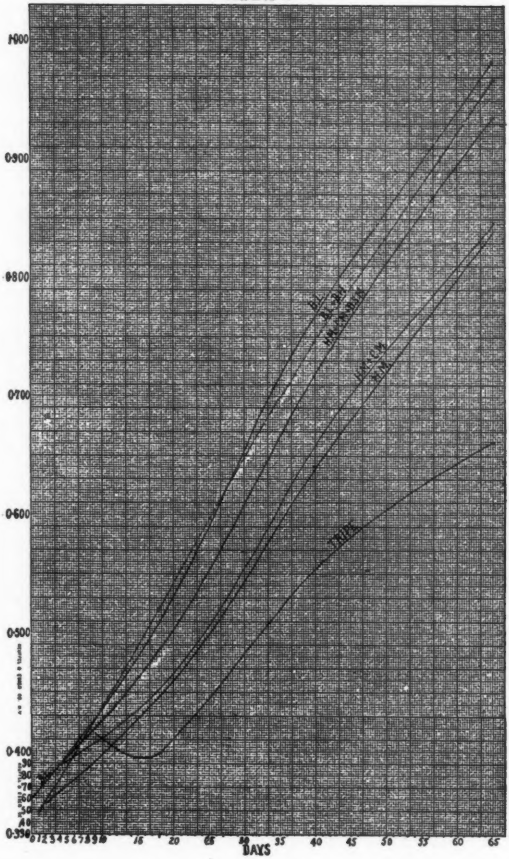


CHART 2



of fact, not at first contemplated, but only substituted when further delay was considered inadvisable.

Rate of Growth and General Discussion

The increase in weight is here assumed to indicate the rate of growth. In Table 1, the data for calculating the rate of growth for the fish of each trough are given.

The rate of growth resulting from each of the ten different diets is graphically shown in Charts 1 and 2 where the logarithm* of the average weight per fish at the different times of weighing is plotted as the ordinate, and the number of days involved as the abscissa. Before drawing these graphs it was necessary to calculate the average weight of each fish for the duplicate troughs. These data are given in Table 2.

The growth curves referred to above were plotted on two charts so as to avoid a too great confusion of lines. That of beef liver as a diet was placed on both charts, so as to provide a ready means of comparison.

Before the fishes were taken over for these experiments they had been fed on beef heart to which a little beef liver was added, the proportion as estimated by the Hatchery Manager being nine parts of heart to one part of liver. The effect of the change of food appears to be reflected in the growth curves. Those of beef heart, and beef liver + beef heart, are nearly straight, while the rest, with the exception of that of beef liver + dry skim milk, show an initial slower rate of growth as compared with that later on. The beef liver curve shows a rather unexpectedly large initial lag. On plotting the growth curves† for the two troughs separately, it was found that this lag was practically identical in both.

Horse meat did not prove to be a satisfactory food when compared with beef liver, beef heart or even beef melt. The addition of clam meal seemed to make it less desirable. The irregularity of the growth curve is difficult to explain. Again a comparison of the growth curves for the separate troughs shows these to be nearly identical for this lag. When dry skim milk, as well as clam meal, was added, very good growth was obtained. As it is difficult to feed just the right amount of food to fishes of this age, it is possible that they did not have to rely very much on the horse meat ingredient.

Beef melt, as seen by the growth curve, shows up quite well after the initial lag is overcome. The fish take to this food readily and eat considerable quantities as shown in Table 3; besides, it keeps their bowels in good condition as indicated by the adherent strings of excrement. It would appear to have possibilities as an ingredient in fish diets.

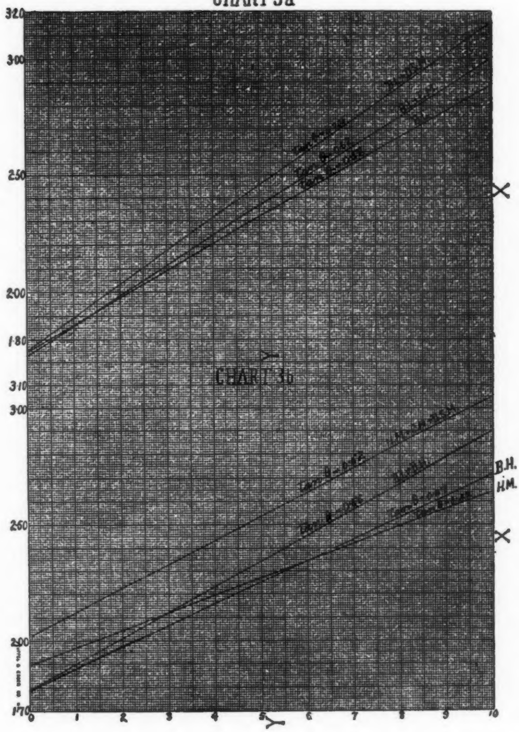
The cooked tripe was quite unsatisfactory. It appeared to be very distastefui and the fish lost considerable weight at first. The mortality, too, was high as compared with that of the other troughs. Eight fish, four from each trough, died, giving a mortality of 8%, while in the remaining 18 troughs, only three‡ died, a mortality of ⅓ of 1%.

*By taking the log. of the weight instead of the weight a graphic representation of the actual rate of growth, as shown by the slope of the line, is obtained.

†The growth curves for the separate troughs are not included. The data will be found in Table 1.

‡One of these deaths was due entirely to an accident and should not really be considered as a mortality in this connection.

CHART 3a



An inspection of the data in Table 2, and also of the graphs will show that with respect to the better diets straight line graphs may be fitted to advantage in order to show the relative gains in weight. Such graphs are shown in Charts 3a and 3b. The values of x and y were computed by the Method of Least Squares, and the slope of the line represents the relative gain in weight and indirectly of size. As a convenient means of comparison, the slope of each line, that is, the tangent of its inclination, is given on these charts. It is obvious that the greater this value becomes, the better will have been the relative value of the diet concerned. It will be seen that the order of the relative values of the diets, as represented by these graphs, is as follows: beef liver + dry skim milk, beef liver + clam meal, beef liver, beef liver + beef heart, horse meat + dry skim milk + clam

TABLE 1

Tr. No.	Diet	Original Weighing	Wt. in Grams	No. of Fish	Aver. Weight	Weight July 28	No. of Fish	Aver. Weight	Weight Aug. 20	No. of Fish	Aver. Weight	Weight Sept. 13	No. of Fish	Aver. Weight	Tr. No.
1	B.L.	July 10	117.5	50	2.35	168.5	50	3.37	318.5	50	6.37	518.5	50	10.37	1
2	B.H.	July 11	104.0	50	2.08	147.5	50	2.95	263.0	50	5.26	420.0	50	8.40	2
3	B.H.	July 11	112.0	50	2.24	153.5	50	3.07	255.0	50	5.10	386.0	50	7.72	3
4	B.L. + B.H.	July 11	112.5	50	2.25	169.0	50	3.38	287.0	50	5.74	467.5	50	9.35	4
5	B.L. + B.H.	July 11	110.7	50	2.21	162.5	50	3.25	285.0	50	5.70	459.5	50	9.19	5
6	H.M.	July 12	117.5	50	2.35	144.5	50	2.89	217.5	49	4.44	342.0	49	6.98	6
7	H.M.	July 12	109.0	50	2.18	135.0	50	2.70	222.0	50	4.44	342.5	50	6.85	7
8	B.L. + D.S.M.	July 12	124.0	50	2.48	179.5	50	3.59	337.0	50	6.74	587.0	50	11.74	8
9	B.L. + D.S.M.	July 12	117.0	50	2.34	169.0	50	3.38	306.5	49	6.26	516.0	49	10.53	9
10	B.L. + C.M.	July 14	115.5	50	2.31	163.0	50	3.26	312.0	50	6.24	543.5	50	10.87	10
11	B.L.	July 10	111.0	50	2.22	155.0	50	3.10	281.5	50	5.63	442.5	50	8.85	11
12	H.M. + C.M.	July 14	128.0	50	2.56	148.0	50	2.96	248.0	50	4.96	380.0	50	7.60	12
13	H.M. + C.M.	July 14	117.0	50	2.34	135.0	50	2.70	212.5	49	4.34	316.5	49	6.46	13
14	H.M. + C.M. + D.S.M.	July 14	126.0	50	2.52	159.5	50	3.19	282.0	50	5.64	448.0	50	8.96	14
15	H.M. + C.M. + D.S.M.	July 14	118.5	50	2.37	147.0	50	2.94	254.5	50	5.09	414.0	50	8.28	15
16	B.M.	July 16	116.5	50	2.33	133.5	50	2.67	248.5	50	4.97	415.0	50	8.30	16
17	B.M.	July 16	117.5	50	2.35	139.5	50	2.79	243.0	50	4.86	397.5	50	7.95	17
18	Tripe	July 19	130.0	50	2.60	124.0	50	2.48	181.0	50	3.62	222.0	46	4.83	18
19	Tripe	July 19	129.5	50	2.59	126.0	50	2.52	183.0	50	3.66	199.0	46	4.33	19
20	B.L. + C.M.	July 14	113.5	50	2.27	146.5	50	2.93	279.0	50	5.58	453.0	50	9.06	20

B.L. – Beef Liver
B.H. – Beef Heart
B.M. – Beef Melt
C.M. – Clam Meat
D.S.M. – Dried Skimmed Milk
H.M. – Horse Meat
Tr. – Trough

meal, beef heart, and horse meat. The diets, horse meat + clam meal, beef melt, and tripe have been omitted on account of the irregularity of their growth curves.

A study of the weights in Table 1, where those of all the troughs are given separately, seems to show a rather interesting tendency of groups of fish having an initial advantage in weight, though small, to not only retain this advantage but to produce an accelerated rate of growth as compared with those in duplicate troughs with slightly lower weight. Of the nine pairs of troughs (those in which tripe was fed is not considered here) five pairs showed this tendency. In these the growth curves for the individual troughs tend to diverge somewhat. A sixth pair shows parallel growth curves; a seventh a convergence, however; while in the eighth and ninth pairs the curves cross each other. These two are those of the horse meat and the beef melt diets.

TABLE 2

Troughs	Diets	Initial Weighing	Aver. Wt.	Aver. Wt. July 28	No. of days	Aver. Wt. Aug. 20	No. of days	Aver. Wt. Sept. 13	No. of days
1 + 11	B.L.	July 10	2.29	3.24	18	6.00	41	9.61	65
2 + 3	B.H.	July 11	2.16	3.01	18	5.18	41	8.06	65
4 + 5	B.L. + B.H.	July 11	2.23	3.32	18	5.72	41	9.27	65
6 + 7	H.M.	July 12	2.27	2.80	16	4.44	39	6.92	63
8 + 9	B.L. + D.S.M.	July 12	2.41	3.49	16	6.50	39	11.14	63
10 + 20	B.L. + C.M.	July 14	2.29	3.10	14	5.91	37	9.97	61
12 + 13	H.M. + C.M.	July 14	2.45	2.83	14	4.65	37	7.03	61
14 + 15	H.M. + C.M. + D.S.M.	July 14	2.45	3.07	14	5.37	37	8.62	61
16 + 17	B.M.	July 16	2.34	2.73	12	4.92	35	8.13	59
18 + 19	Tripe	July 19	2.60	2.50	9	3.64	32	4.58	56

This tendency would appear to show the necessity of the careful selection of fish for feeding experiments in order to get them as nearly equal in size as possible. Incidentally, this may also show a racial difference in fish, a view which careful observations of growing fish undoubtedly support. There is little doubt but that selective breeding, even that of mass selection, would materially raise the quality of the fish.

A record of the amount of food fed was also kept, but as the experiments were conducted for so short a time, and that during a period of the life of the fish when it is difficult to estimate the optimum amount to feed, the calculated efficiency of the diets is no doubt lower than it should be. In the following table, Table 3, the total weight of each diet fed, the total gain of the fish on the respective diets, and also the calculated amount of food fed per gram gain in weight, are given. The amount of tripe fed means very little, as most of the food was swept out in cleaning the troughs.

In making these calculations the mortality of the fish was not taken into account, for with the exception of those fed on tripe only three died and these from troughs where different diets were fed.

It will be noticed, Table 3, that the ratio for the beef liver + dry skim milk is 3.3 to 1. It must be remembered that the skim milk was added dry, and that if the ratio were computed on the basis of liver being 65% water the calculated result would be less satisfactory. The ratio would, in fact, be 4.6 to 1. Nevertheless, as the dry skim milk can be purchased in bulk at*twelve cents per pound, while ten cents per pound is paid for liver, the actual lower cost of the dry skim milk more than compensates for the less favourable ratio; besides there is the increased growth of the fishes to be taken into consideration.

TABLE 3

Diet	Total weight of food fed	Total gain in weight of fish	Weight of food per gm. gain
B.L.	2726.7 gm.	732.0 gm.	3.7
B.H.	2325.3 gm.	590.0 gm.	3.9
B.L. + B.H.	2735.6 gm.	703.8 gm.	3.9
H.M.	2360.0 gm.	458.0 gm.	5.0
B.L. + D.S.M.	2874.0 gm.	862.0 gm.	3.3
B.L. + C.M.	3278.3 gm.	767.5 gm.	4.3
H.M. + C.M.	2469.0 gm.	451.5 gm.	5.5
H.M. + C.M. + D.S.M.	2697.0 gm.	617.5 gm.	4.4
B.M.	3225.0 gm.	578.5 gm.	5.6
Tripe	1356.8 gm.	161.5 gm.	...

From the results obtained with the beef melt one cannot help but suggest again it merits consideration as a constituent of fish diet. Although its ratio is high its actual cost at 2.5 cents per pound is very low.

The addition of clam meal to the diet must also be favourably commented upon according to the results obtained with beef liver + clam meal. Inspection of Charts 1 and 2 shows this diet to have produced nearly as good a growth as that of beef liver + dry skim milk. Unfortunately the supply of the meal in bulk cannot at present be depended upon.

Before closing this discussion mention of the short time available for these experiments might again be made. It is realized that feeding experiments with fishes should extend over a considerable period of time, but as the results obtained in this investigation indicate rather fundamental tendencies, they are submitted with this in mind.

The writer is much indebted to Mr. H. H. MacKay, Biologist and Director of the Fish Culture Branch of the Ontario Department of Game and Fisheries, for his inspiration and advice.

*January, 1931, quotations on dry skim milk are less than six cents per pound.

Discussion

MR. BRANION (Ontario): It is certainly a great pleasure to realize that such basic investigations are being carried on in respect to fish nutrition. In nutritional studies on mammals it has been found necessary to select standard animals for experimental work. I should like to ask if the various workers have taken into consideration the fact that it will be necessary in the near future to develop a standard fingerling for this type of work.

MR. DETWEILER: I think that it would be desirable to do so. In my experience I find that different troughs and even individual fish in the same pool, treated in the same way, yield varying results.

MR. TITCOMB: I would like to ask Mr. Detweiler if he weighed the food so that he would know at the end of the test the amount of food actually used. When using mixed food, i. e. clam meal and liver, do you ascertain whether the clam meal is digested and utilized?

MR. DETWEILER: We weigh the foods both on their way in and on their way out. We try to keep just enough in the trough to be sure the fish have sufficient. If you put in too much mixed food they will take out what they like and leave the rest.

MR. TITCOMB: Do you find that they eat the clam meal?

MR. DETWEILER: They seem to, although they do not take it quite so readily as they do some other foods. May I ask whether anyone else has tried tripe?

MR. COBB: Just enough honeycombed tripe to see if the fish would take it.

MR. DETWEILER: They do not take it, do they? Did you try spleen?

MR. COBB: Yes, the fish seemed to take it as readily as any food.

Although I am much interested in this work from the scientific point of view, I may point out that our chief interest is the production of good sized, well shaped, healthy fish for stocking the streams. In Connecticut, where the fishermen no longer care especially for fingerlings, we are in the position that when we have a lot of fish which do not do well we have no ready way of disposing of them. In trying out these different foods we have taken into consideration the appetite of the fish, the availability and price of the foods, the mixtures which can be used, their physical condition, and, above all, the results.

Concentrated milk or buttermilk, which comes in paste form, cannot be used alone but it can be fed along with the meats in a mixture containing dry food. Concentrated milk or buttermilk can be used instead of water to moisten the mixture, but since the same result is obtained by using more dried milk and water, its use has been discontinued.

Powdered milk has been used in a mixture with meat. Ten per cent of milk can be mixed with meat and fed with no additional water. In a mixture of one-third milk and two-thirds meat, two pounds of water are mixed with five pounds of meat and two and one-half pounds of milk powder are added. This mixture has about the same stiffness as 10 per cent milk and 19 per cent meat mixed without water. When using milk never use enough water to cause any wet substance to show and never mix so that dry milk will show. Either of these conditions will cause waste.

Dried buttermilk can be used the same as milk if desired. It is not readily soluble, and 20 per cent can be mixed with the meat without water. It will in time take up as much moisture as the milk and so should be used in the same manner. To some extent

we feed dried buttermilk with mixing. For instance, if you feed in the forenoon dried buttermilk alone the trout will take it readily if it does not wash against the outlet screen.

Our fish will not take clamheads. If they do they spit them out. A careful examination of the refuse in the ponds will show the presence of clamheads if any large amount is used. We have therefore kept down the quantity of clamheads to a point where they are disguised in the meat. We put the clamheads in just sufficient water to moisten them. One pound of heads will absorb one and one-quarter pounds of water. We then mix them with the meat and run them through the Enterprise cutter. The mixture is such that it is hard for the fish to discard the clamheads. Thus we feed clamheads to our large fingerlings and to our adult trout with apparently good results. We mix, moisten, and grind 10 per cent dry clamheads with 90 per cent meat. To 80 per cent of this mixture we mix 20 per cent milk or buttermilk. This makes a mixture of approximately 66⅔ per cent meat, 6⅔ per cent clams, 8 per cent water, and 18¼ per cent milk. It is best to add one pound of water to each 15 pounds of mixture. A bucket of mixed meat and milk is heavier than meat alone and so the trout take a good deal more food than they would with the meat alone. In feeding two-thirds meat and one-third dried milk, the trout consume about 50 per cent more food than when fed on meat. The gain in growth of these fish is 50 per cent more than on a meat diet. We had a much better weight in our fish, which were uniform in size, while the fish fed on meat alone varied considerably. The larger fish which had been meat fed were fully as large as those fed on the mixture, but in addition there were a great many small ones.

I am of the opinion that beef liver is not the only meat to be used. It is good, easily prepared and is convenient for feeding fry, but I think we have been too much inclined to feed one kind of meat and have not given enough consideration to the possibility of various combinations. So far as meat is concerned we start with beef liver, then add sheep liver, hearts, and plucks. Eventually we work to a diet which contains a mixture of available foods. I am of the opinion that the fish do better in the long run on this mixed diet than on any one diet. I believe that if you hold fish down to one diet it is not conducive to good growth. I believe that a trout is essentially a meat eating fish, but that certain other foods provide additional substances which are very useful. In feeding trout you must consider not merely weight alone, but also strength, appearance, shape and other qualities which combine to make an ideal trout. With our improved feeding we have increased the average size of the yearlings which we are distributing. Milk is one substitute that is a factor of real significance in this increase, although other materials no doubt contribute a share.

MR. LORD (Vermont): I am interested in the feeding of clamheads, because at our experimental hatchery at Pittsford, Vermont, we have consistently found that clamheads give wonderful results. In this connection it is interesting to note a comparison of the growth of the fish receiving beef liver as against 75 per cent beef liver and 25 per cent of the finer ground clamheads. In the early part of the season the fish fed on the beef liver took the lead, and I noticed that the fish receiving the 25 per cent clam meal at first did not take it, as the particles were too large for them; but before the season had ended, the fish receiving the 25 per cent clam meal in addition to beef liver had caught up to the others, and by the end of the season averaged three or four grams larger than the fish fed on beef liver. Dried buttermilk, as Mr. Cobb has said, has also

proven very satisfactory. We consider it better than the skimmed milk because it is so much less soluble and can be fed with but little waste.

I was also interested in the idea of producing a good looking fish. We have produced fish fed with dried salmon eggs in our hatcheries equal in appearance to any wild fingerlings. Dried salmon eggs with 50 per cent beef liver were produced in the hatchery fish of beautiful color, whereas the beef liver fish were the ordinary dull colored hatchery fish.

Mr. Titcomb: May I ask how long the salmon eggs were fed.

Mr. Lord: We started in April when the trout were a little over an inch long. When you start feeding experiments in April you bring in another factor, that of early mortality. The color is noticeable in a couple of weeks and keeps getting brighter all the summer. We have at the present time three and four inch fingerlings in the hatchery with bright red spots. We fed an experimental lot of yearlings with salmon eggs and beef liver for a month, and they began to show a distinct coloration.

Mr. Chute (Chicago): Wild fish seem to hold the color better, although in captivity they do not live as well as hatchery fish. In the aquarium we do not have to work on such large quantities of food as it becomes necessary to handle in the hatcheries, therefore we can furnish a larger variety of food. In the aquarium we feed our trout liver, beef heart, and raw fish. I like to use salt water fish because I think the salt is beneficial. We also use smaller fishes or crustaceans. Of course in hatchery practice it would not be convenient to furnish the trout with live food of that kind. We try to provide as varied a diet as possible, but I do not believe any aquarium has yet succeeded in keeping the color after the fish have been in captivity any considerable length of time.

Mr. Titcomb: I would like to ask Mr. Lord if he has fed the trout on salmon eggs from the fry to the adult stage.

Mr. Lord: The experiment is not yet finished; we started only this season. Salmon eggs, by the way, are a dried product, and are obtained at a relatively low cost, twelve cents a pound. It is called Kenney's fry food.

Mr. Titcomb: You are going to continue feeding these fingerlings through the year on salmon eggs?

Mr. Lord: All our fish are going to get some salmon eggs from now on.

Mr. Cobb: You could not say definitely how long it would be safe to feed those salmon eggs, or whether it would be safe to feed them continuously?

Mr. Lord: The salmon eggs are not fed by themselves but are mixed with the meat.

Mr. Cobb: Would you consider it a safe diet from the fingerling stage to the adult?

Mr. Lord: I think it would be a perfectly safe thing to include dried salmon eggs in the diet.

Mr. Cobb: If you used salmon eggs for a short period before putting trout out, what would be the minimum time for feeding salmon eggs?

Mr. Lord: I cannot tell with respect to the smaller fish, but I would say if you are going to plant yearlings that four to six weeks feeding would give nice appearing fish.

A QUANTITATIVE METHOD OF STUDYING THE FOOD OF SMALL FISHES

E. W. Surber

Special Investigator, U. S. Bureau of Fisheries

A study of the food of over nine hundred small fishes taken from sloughs of the upper Mississippi River has just been completed. The original purpose of the study was to determine the relationships existing between these fish and their available or potential food supply. It was hoped that the results of the examinations of the intestines of these fish would reveal: (1) The kinds and proportionate number of organisms selected by the various species of fish for food. (2) The degree of selectivity exercised by them in taking the food available in their environments as measured by quantitative methods.* No better way of checking the efficiency of present methods of studying available fish food supply, it is believed, can be found than by such a direct method.

Numerous studies have been made of the food of various species of fish without any previous quantitative study of the available fish food at the collecting station. As a result of these omissions, probably often necessary through lack of time or equipment, we have the following situation existing: A worker selects a species of fish for a study of its food and examines several hundred specimens from a pond or lake or several ponds and lakes in his vicinity. Another worker in a different part of the country does likewise. The danger of comparing the results of the two workers is at once apparent. One of them may find that the species of fish he is working with apparently shows a preference for some kind of organism that may be entirely absent from the environments of the fish species from another locality. Such studies, although perhaps incorrectly claiming some feeding preference, often serve a good purpose in demonstrating the cosmopolitan nature of the feeding habits of some of our common species of fish.

The quantity of food organisms present on or in the bottom materials or plants in sloughs of the upper Mississippi River bottoms have been expressed in numbers per square meter, and of plankton organisms in numbers per cubic milliliter or liter.

In the method about to be described it was desired to express food organisms in numbers, since it promised to allow one to arrive at comparisons of food consumed and that available with more definiteness than the method employed extensively by Pearse and many recent workers.†

*Bottom fauna studies were made with the Petersen sampler; plankton samples were collected with a pump and strained through a Wisconsin quantitative net of silk bolting cloth No. 20.

†In this method the percentage by volume which each kind of food organism constitutes of the total volume of food is used in recording results.

Pearse (1924, p. 254) calls our attention to this very important fact that "it will not be possible to estimate, in a scientific way, the number of animals that each type of environment is capable of supporting until the rate at which each species is consuming materials from the various food resources is known."

The determination of the rate at which fish are consuming food materials in their environment seems very difficult without the use of numerical counts, hence the method here described.

The young fish preserved in 10% formalin solution were first measured, then their alimentary tracts were removed and split open from end to end. The contents were removed by scraping the intestinal wall with scalpel or forceps. The latter operation was performed in a petri dish containing the preservative in order that none of the material (including the algae) would escape. The contents of the fish were then transferred to vials which were numbered and saved for later examination.

The examination of the intestinal contents was performed in this manner: The entire intestinal contents were poured into a petri dish 70 m.m., inside diameter which had been divided into 19 equal sectors with a diamond point pencil to facilitate counting. An "X" was placed in one sector for a point of reference. All recognizable objects which represented the *body* of a food organism were then enumerated under the high power of a binocular microscope on a raised stage where light came *from below*. If, for example, water boatmen had been consumed and the heads had become disjointed from the partly disintegrated body, the heads only were counted. In some instances where various water fleas were present in large numbers, it was found convenient to count the eyes only when their transparent or nearly transparent bodies were bunched or stuck together.

The identification of organisms in the intestines of these fish was surprisingly easy after having first studied the food available in their environments.

Occasionally more food material was present than could be handled or counted in one dish, in which case the portions making up the whole were examined separately.

The algae, particularly diatoms, were necessarily neglected in the count under the binocular with the exception of large filamentous forms such as *Spirogyra*. When bits of leaves or stems of larger aquatic plants occurred, an estimation in percent of total volume was made of that portion which the plant material constituted.

In order to take the algae into account in this study, the following procedure was used: After examining the intestinal contents of a fish, as described above, the entire contents were poured into a centrifuge tube. The material was then concentrated to a small volume by centrifuging.*

After pouring off most of the supernatant water a large portion or

*A hand centrifuge with 15 c.c. tubes was used for this work.

Food of Small Slough Fishes
Seine Haul Station No. 11
Gibbs Slough—Trempealeau, Wis.
Food items in no. of individuals per fish

Available Food	Sampling Stations: Station 1	Station 2	Station 3	Golden Shiner (Notemigonus crysoleucas)	do.	Black Bullhead (Ameiurus melas)	do.	do.	Great northern Pike (Esox lucius)	Yellow Perch (Perca flavescens)	do.	do.	do.	do.	Wall-eyed Pike (Stizostedion vitreum)	do.	do.	do.	do.	do.	do.	do.	do.	do.	Black Crappie (Pomoxis sparoides)	do.	do.	do.	do.
Length in mm				82		44	58	70	74	18	22	17	37	36	54	54	56	56	43	50	43	61	66	75	11	31	30	31	30
Plankton (Sedgewick-Rafter Count) No. of organisms per c.c. / No.	Station 1 Shore 30' Depth 2'	Station 2 Shore 45' Depth 2'	Station 3 Shore 11' Depth 1'	145	144	148	145	147	151	157	158	161	170	171	148	149	150	152	153	154	156	173	174	175	160	176	177	178	179
Myxophyceae:																													
Aphanizomenon		.60	51.60		8+					4																			
Heterophyceae:																													
Ceratium	.38	.80	.25																										
Nitzschia		.10			6			4																					
Fragilaria			.12																										
Melosira	11.22	5.00	4.51	1	2		2	2		2			2	20															2
Rotifera: Polyarthra	1.03	.30	.69																										
Anuraea	.31	.10	.25																										
Entomostraca:																													
Cyclops	x																												
Nauplii	.12	.20	.12																										
Bosmina		.10																											
Chydorus			x																										
Unmeasured Algae:																													
Gloeocapsa													5																
Navicula							1	10																					
Pleurosigma				1	3		4	9						1															
Frustulia				1	4	4	1	6																					
Cocconeis				1				1																					
Diatoma							1																						
Tabellaria								1																					
Scenedesmus						1																							
Closterium							1																						
Surirella						1																							
Per cent algal food					4	1-	3	10		1-			1-	4															1-
Zooplankton No. of organisms per liter	Station 1 N End	Station 2	Station 3																										
Rotifera:				1																									
Asplanchna	3.87	2.00	3.87																										
Polyarthra	43.86	79.00	153.51																										
Anuraea	3.87	3.00																											
Noteus		1.00					1	1																					
Entomostraca:																													
Ceriodaphnia			7.74		1		12	5		3	23			15								3	8			5	123	2	6
Bosmina	6.45	9.00		3	3		3			1	1				1	1					3	1	2		4			2	5
Chydorus			3.87		3	62	36			7	17	23		11	6	15	6	7		6	14	3	42	39	113	32	15	71	123
Cyclops	1.29	3.00	3.87																							27		54	
Nauplii	18.06	41.00	29.67																										
Unmeasured																													
Daphnia										14	6	3	6	74								2	1				3		
Eurycercus						1						1																	
Alona																												1	
Bottom Fauna No. of organisms per m²	Station 1 Shore 6' Depth 2½'	Station 2 Shore 90' Depth 5'	Station 3 Shore 10' Depth 2'																										
Coelenterata:																													
Hydra			13.56																										
Platyhelminthes:																													
Planaria	40.68																												
Nemathelminthes:																													
Nematodes	1,383.12		1,342.44																										
Chaetopoda:																													
Oligochaeta	2834.04		2,793.36																										
Hirudinea: Leeches	27.12		13.56																										
Mollusca:																													
Planorbis			13.56	16																									
Musculium	691.56		420.36																										
Crustacea:																													
Cladocera: Chydorus	27.12							9																					
Copepoda: Cyclops	216.96		67.80			2	84			14	2	2	2	28		1						5		2			2		35
Canthocamptus	54.24		244.08																										
Ostracoda:	461.04		257.64	1	1	6	131	17					3							1				7		21	4	8	20
Isopoda: Asellus	237.69		339.00				1																						
Amphipoda:																													
Hyalella	1,600.08		162.72			5				2		2		4	1														
Hydrachnida:																													
water mites			13.56				1																						
Ephemeridae:																													
Caenis	27.12																												
Hemiptera:																													
Plea			54.24				2																						
Belostoma	271.20																												
Diptera: Chironomidae	3,783.24		3,498.48		2	11	35	17		1				1												1			1
" pupae	13.56																												
Ceratopogon	135.60		94.92																										
Coleoptera:																													
Haliplus	271.20		94.92																										
Unknown	67.80																												
Unmeasured:																													
Seeds				80%	85%																								
detritus								30%																					
Corixa											1	3																	
Fish															1	1	1	1	1	1	2	2	1	1					
Diaptomus																												1	

all of the material in the bottom of the tube was transferred directly to a Sedgewick-Rafter counting cell placed under the low power of a compound microscope. Large organisms, such as Odonata nymphs, were removed from the petri dish before the material was transferred to a centrifuge tube.

The material in the Sedgewick-Rafter counting cell was gone over carefully in search of algae. From ten to thirty fields were examined and the algae observed enumerated. This enumeration afforded an abundance ratio of the various organisms present. If algae were present in considerable numbers, an estimate was made of the percentage which they constituted by volume of the intestinal contents.

No attempt will be made to present the results of the study here. The accompanying table illustrates some of its possibilities:

EXPLANATION OF TABLE

X=The presence of an organism in the Sedgewick-Rafter counting cell but which was not enumerated in the count of organisms in ten fields.

A = Abundant, AA = very abundant.
C = Common.
S = Scarce.
R = Rare.
m^2 = one square meter or .83 square yards.
liter = approximately one quart.
1 c.c. = $\frac{1}{1,000}$ of a liter.

X is used to indicate degree of predominance of the different kinds of bottom materials in the bottom sample. For example: Sand — XX, Mud — X indicates that sand is twice as abundant as mud.

In this table are presented the number of available food organisms as measured by quantitative methods inside the area covered by the seine.

This table is in effect a correlation table presenting at once similarities, peculiarities, and a concrete picture of the food of the fish examined in a manner which the writer believes is very readily comprehensible. It also illustrates the degree of accuracy with which the food of the fish had been measured.

One of our most important problems in quantitative work relative to available fish food is to obtain a definite idea of the amount of food which our fish eat in a unit period of time. That, of course, is dependent on such factors as the size or age of the fish and the temperature of the water.

The need for more work in this field is of paramount importance when we consider how little is known about the amount of food required by most of our common game fish. Quantitative studies of bottom or weed fauna will be of little practical value until this problem is solved.

Although the writer has secured much data on the numbers of the various kinds of organisms found in the habitats of the fishes studied and the numbers and kinds of these organisms selected by them for food, there still remain excellent opportunities for more complete analysis.

Given the following information which we hope to obtain through supplementary studies it should be possible theoretically, at least, to study a fish environment and estimate with greater accuracy its potentialities as a fish producing environment.

1. A knowledge of the abundance of bottom, weed-dwelling and plankton organisms in a comparatively small environment (to start with) where several species of fish are thriving. Sloughs of the upper Mississippi River bottoms afford habitats of a variety of sizes and kinds which will constitute a good starting point for this work.

2. A knowledge of the numbers of organisms consumed by fish during a unit period of time. If we assigned a hypothetical seventy-two hour value as the maximum time for complete digestion or passage of food through the alimentary tracts of the fishes whose intestinal contents are revealed in the above table, it is evident that we can get somewhere in estimating how much food might be consumed by these fish during the warmer months of the year.

3. The rate of digestion of natural food materials. The ideal manner to attack this phase of the problem is directly by the experimental method. This method was adopted by a few workers, namely, Putter (1909), Petersen (1918), Pearse (1920) (1924), Hathaway (1927). Pearse has been the most notable contributor to our knowledge of the volume and number of various kinds of organisms eaten by several species of our common warm water fishes. However, he has attacked the problem from the volumetric viewpoint, or a combination of volume and numbers, which appears to be difficult to tie up with numbers of organisms as customarily expressed by limnologists. We have attacked the problem from the "numbers" viewpoint, which seems to show better promise of getting at fish food evaluations of aquatic environments.

Intestinal parasites are frequently found in the small fish from the sloughs and can be readily enumerated. Correlations between kinds of food and kinds and numbers of parasites may lead to the discovery of intermediate hosts of the parasites.

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Discussion

MR. RICKER: What species of fish have you examined?

MR. E. W. SURBER: All species, including large-mouthed black bass, bluegill, and "pumpkin seed" sunfishes, black and white crappie, and several species of minnows, such as golden shiners, emerald minnow, etc.

REARING A BROOD STOCK OF BLACKSPOTTED TROUT

Russell F. Lord

U. S. Bureau of Fisheries, Pittsford, Vt.

Eggs from wild blackspotted trout are secured in great abundance at many places in the west, the waters of Yellowstone Park alone yielding from three to twenty million. With such an abundant supply of wild eggs it is little wonder that few attempts have been made to maintain brood stocks of domesticated fish at the hatcheries. It would seem, however, that the time is close when it will be necessary to do this very thing, for there is little doubt that the blackspotted trout has been suffering a decline in abundance in many parts of its range. Several reasons have been offered but it seems evident that a few good collecting fields, no matter how prolific, are unable to meet the greater demands of an ever-increasing number of fishermen. The history of the eastern brook trout is being repeated. In the case of this fish, states and government tried at first to bring back the depleted streams by drawing upon wild fish for the egg supply, but soon found out that wild stock could not keep itself up and still supply the demand of those depleted streams. Hatcheries were then forced to rear and keep their own brood stocks of brook trout to guarantee a source of eggs.

I can find on record but few attempts to domesticate the blackspotted trout at a government hatchery. When the Springville, Utah, station was established some twelve or fifteen years ago, it was planned to develop brood stocks of rainbow, blackspotted and brook trout. The commissioner's report for 1920 states that the rainbows and blackspots were doing well. In the next report we read that the first eggs from the blackspotted trout were taken between March 20 and May 21, 1921. It was also stated that had spawning conditions been more suitable better results could have been obtained. 107,800 eggs were taken at this time. At the next spawning season in the spring of 1922, however, much disappointment was experienced as 240 females three years old yielded only 23,000 eggs. I will quote from the station's report.

"No satisfactory explanation of this failure is at hand, except that it seems to coincide with the results of past efforts to domesticate this species of trout at other stations of the bureau."

The fish in question were reported to have made a good growth and appeared very healthy.

The next stripping of the blackspots at the Springville hatchery was also unsatisfactory, and we read, "Having failed for two successive years to secure any results from . . . holding a brood stock of native trout as a source of egg supply, it was decided to liberate the fish in suitable waters and abandon the attempt. The number of eggs taken in each instance was negligible and their quality very

poor." And as far as I know, this was the last attempt by the Bureau to keep up a brood stock of domesticated blackspots.

Such was the situation when the Pittsford, Vt., station was taken over by the Division of Scientific Inquiry as an experimental trout station. The problem of raising a brood stock of blackspotted trout offered an interesting subject for investigation. A consignment of eyed eggs was received from the Yellowstone on July 5, 1926. Hatching was practically complete during the next ten days and by August 4 the fry were feeding readily. At the end of the month they were put into a small spring water pond and since then have been retained at the Pittsford hatchery in various small ponds. The fish have stood for considerable handling, being moved from pond to pond at inventory time and some were even exhibited at a county fair with no apparent ill effects. After the first year their ration consisted of fifty percent fresh meats and fifty percent clamheads with some shrimp bran.

In the spring of 1929 these fish appeared to be of spawning size, but examination proved that only a few of the largest males were ready. During the past April, just one year later, the fish were examined again and this time both sexes were found to be ripening. On April 15, the first ripe female was found, and on going over all the fish, 17 of them were found with eggs ready to be taken. These females were of moderate size, ranging from ½ to 1¼ pounds in weight. They were very vigorous and healthy and of excellent body proportions. From the 17 fish a little better than 15,000 eggs were secured, the eggs appearing to be of fine quality even as they flowed from the ripe fish into the spawning pans. The trout themselves handled nicely and stripped even easier than ripe brook trout of equal size.

The incubation of these eggs was watched with interest as they came to the eyed stage with a loss of only 6%, 14,318 eyed eggs being measured at 388 eggs per fluid ounce. The eggs hatched into vigorous fry with very little loss.

I have here a table showing the dates on which eggs were taken, the number of fish stripped, yield of eggs, percent eyed and so on,

BLACKSPOTTED TROUT SPAWNING AT PITTSFIELD, VERMONT
1930

Date	*No. Eggs Taken*	*% Eyed*	*No. of Fish Stripped*
April 15	15,172	94%	17 fish unselected
25	26,298	80%	17 fish largest available
	32,745	95%	32 fish unselected
May 3	23,755	95%	21 fish unselected
8	17,767	93%	17 fish unselected
Total	115,737	Av. 91.4%	104 total female stripped

which I will not bother to read. Suffice it to say that 104 fish gave us 115,737 eggs of which an average of 91.5% were brought to the eyed stage. This percent would have been even higher had not eggs from one day's take eyed up at only 80% against a 94%, two 95%'s and one 93%. There were 26 small females in our brood stock that did not spawn.

These eggs from hatchery raised brood stock were without doubt of excellent quality. Those retained at the station hatched with but slight losses and at present we have thousands of blackspot fingerlings an inch or more in length. A shipment of 49,000 eyed eggs sent to Bozeman, Montana, on May 17 also did very well, and the latest report I have on these is that early in July 47,000 fry were feeding nicely.

I must admit that the good results with the blackspots came as a surprise, especially when considering the generally accepted idea that the fish did not take to domestication very readily, and that, in addition, the environmental change from Yellowstone waters to Vermont waters was considerable. The next spawning season will be of even more interest to see if the eggs from our brood stock remain of the same high quality. Fingerlings of this season's hatch will of course be held to spawning age again next season, and so on until we have developed, I hope, a strictly domesticated strain of blackspots. The time is surely coming when it will be necessary for trout and even bass stations to put forth even greater efforts towards rearing their own brood fish, and I am glad therefore that our initial experiments with the blackspotted trout have been so successful.

A PRELIMINARY REPORT UPON SOME IRRADIATION EXPERIMENTS

MARY CROWELL

Assistant in Charge of Food Nutrition Laboratory, State Fish Hatchery, Burlington, Conn.

The successful use of the ultra-violet ray in the treatment of many diseases of animals and human beings may possibly bring about new methods in the treatment of fish diseases. Up to the present, about the only way of dealing with sick fishes has been some sort of "dip". With trout, we have the acetic acid dip for gyrodactylus, the salt dip for fungus, or the salt dip for costia. It is practically impossible to give any kind of internal dose. Fishes offer a unique problem in this respect. And, of course, we run up against such diseases as furunculosis where dipping has not been effective. The violet ray lamp offers one possible means of treatment in such cases, provided it will kill the bacteria without harming the fish.

An overdose of ultra-violet ray will kill an animal. It has been found that the amount of light which will prove lethal is directly proportional to the size of the animal. That is, the smaller the animal, the shorter the exposure it will take to kill it. Now, organisms infecting fishes are so much smaller than the fishes themselves that it should be possible to find exposures sufficient to kill the parasites without harming the host.

The experiments here described were suggested by Dr. C. M. McCay and carried out under the auspices of the Connecticut State Board of Fisheries and Game at the Burlington Trout Hatchery. The lamp used was an Uviarc Poultry Treater—provided through the courtesy of the General Electric Vapor Lamp Company of Hoboken, N. J. The lamp was suspended over a rearing trough having a depth of constantly running water of 6¼ inches, in such a manner that the distance of the lamp from the water could be changed at will. A wire box about 12 inches square and 3 inches deep was placed in the trough to confine the fishes while they were subjected to treatment. A smaller screen was made to fit into this box so that the fish could be confined between the two screens and irradiated in any depth of water.

In such an unfamiliar field, it was difficult in the time allowed to plan a consecutive series of experiments which might definitely establish any truths. In the first place, there were three variables to work with; viz. (1) the time of exposure (2) the distance of the lamp from the water and (3) the depth of the water. Logically, the minimum amount of any of these which would still be effective would be the most practical. The main problem here dealt with has been the resistance of normal brook trout to the ultra-violet ray. Healthy brook trout, fry and fingerlings, of average weight and length, were used for irradiations unless otherwise stated. During the experiments,

they were cared for the same as other trout in the hatchery. They were held for several days after exposures to watch for any after effects.

The first few experiments were planned to discover whether the rays would affect the trout at all. The results were disastrously positive. Ten trout were exposed in four and one-half inches of water for two hours with the lamp five inches from the water. At the end of the two hours, one fish had died, two had turned over and the rest were so badly burned that they all died before the next morning. Exposure of another group under the same conditions caused the death of three within twelve hours. In the two above experiments, the fishes were allowed the range of the entire four and one-half inches of water. They remained for the most part one to two inches from the top of the water. Practically the same results were obtained in one inch of water. A twenty minute exposure under the above conditions was not harmful, nor was one of thirty minutes in four and one-half inches of water with the lamp two feet from the water.

The next few experiments cover the results of successive exposures under varying conditions (Table 1). In general, it may be deduced that repeated exposures of short periods prove more effective than a single exposure of a long period. The data show that exposures at intervals of forty-eight hours are less harmful than at intervals of twenty-four hours, that the lamp is much less potent at a distance of twelve inches than at six inches, and that the total length of time required to kill a fish is less with successive short exposures than with one long exposure.

Statements have been made that most of the effective irradiations of the ultra-violet light are cut out by an inch layer of water. From the following experiments, one much conclude that the irradiations are still effective at a depth greater than that. The temperature change caused by the light was never more than two degrees, even over periods of an hour or more, so that could not have been responsible for the effect (Table 2).

A very little work has been done with diseased fishes, and this brings out a few interesting points. Trout severely infected with gyrodactylus were exposed for three minutes in one inch of water with the lamp eighteen inches from the water. The pectoral fins of some of these trout were then examined. They were infected just as severely as before. Another group was irradiated for five minutes under the same conditions with no effect. Then a group was exposed for five minutes in one inch of water with the lamp six inches above the water. When examined only a few flukes were found. Exposure for ten minutes under the latter conditions was so effective that only two worms were found on five pectoral fins. A seven minute exposure proved nearly as effective as the ten minute one.

The trout apparently were not harmed by these short irradiations.

TABLE I

Date	Exp. No.	Depth of Water	Distance of Lamp From Water	Time of Exposure	Time Between Exposure	No. of Exposures	RESULTS
June 17-22	VII	1 in.	6 in.	3 min.	24 hr.	5	Three dead June 20. Four more June 21. Rest June 22.
June 17 –July 7	VIII	1 in.	12 in.	3 min.	24 hr.	16	Appeared ragged and sluggish June 21. One died June 26, two June 30, one July 3, two July 4, one July 6, two July 7.
June 24 –July 8	IX	1 in.	6 in.	3 min.	48 hr.	5	Appetite all right until June 28. One died July 1, one July 7. July 8 all looked about to die.
June 24 –July 8	X	1 in.	12 in.	3 min.	48 hr.	5	No mortalities. Not in very bad shape when discarded, but not normal.

TABLE II

Date	Exp. No.	Depth of Water	Distance of Lamp From Water	Time of Exposure	Time Between Exposures	No. of Exposures	RESULTS
June 30	XV	Lower screen 4 in. Upper screen 3 in.	6 in.	90 min.		1	Very grayish when removed. Appeared badly burned next morning. Two died in afternoon.
July	XVII	Lower screen 4 in. Upper screen 3 in.	6 in.	3 min.	24 hr.	10	Did not eat well after first few exposures. One died July 30. Appeared burned and sluggish. Would not eat at all when discarded.
Aug. 5 –Aug. 11	XXI	1 in.	12 in.	90 min.		1	One died A.M. Aug. 6. Another turned over P.M. All appear burned.
	XXII	Lower screen 4 in. Top screen 3 in.	9 in.	90 min.		1	One died Aug. 7. No vitality. Similar to XVI.
	XXIII	Lower screen 6 in. Top screen 5 in.	7 in.	90 min.		1	No mortalities. All appear sluggish. Similar to XVI and XVII.

After the first day, there was no loss of appetite, no sluggishness, nor grayish appearance.

Whereas in treating an external parasite like gyrodactylus, severe irradiations of short period prove effective, the opposite might be true in combating blood diseases. It has been found that irradiation in one inch of water with the lamp twelve inches away for one minute a day for ten days or more does not prove harmful. Irradiations in one inch of water with the lamp eighteen inches away for three minutes a day produced no ill effects on the fishes. Such treatment might be beneficial in fighting other diseases.

Little of definite value has been accomplished as yet along this line, but it offers wide and interesting research in a new field.

Discussion

Dr. Hubbs: Most of the serious losses in Michigan on account of trout diseases are due to gill bacteria. Unless the ultra-violet rays penetrate bone, they would not operate through the opercle on the gill tissues.

Mr. Branion: Have you ever noticed any effect on the eyes of an over dosage of ultra-violet light?

Miss Crowell: In cases where the fish were killed they became blind before they died. I do not consider that it hurt the eyes when it did not harm the fish in general.

Mr. Branion: Have you carried out any experiments with regard to the depths to which ultra-violet light will penetrate?

Miss Crowell: Although it has been stated that ultra-violet light would not penetrate or was not effective in depths of more than one inch, I found there was an effect on the fish in depths of four and a half to five inches of water if the exposure was sufficiently long.

Mr. Branion: In studying irradiation with various animals, I have noticed that human beings cannot stand as much irradiation as other animals. It seems to affect the eyes of humans to a much greater degree. The penetration of sea water by ultra-violet light would seem to be the only reason for the development of the vitamins in cod liver oil. It would be interesting for somebody to follow out the effect of heavy doses of ultra-violet light on fish. From a technical and histological viewpoint it would give some indication of the effect of these irradiations on different types of fish comparable with the other animals.

ATTACK ON THE FISHERY PROBLEM

A. G. Huntsman

Director, Biological Station, St. Andrews, N. B.

It may be thought odd that we should speak of a fishery problem, as if there were only one, but it would seem to be quite legitimate to consider that there is a central one, the problem of how to have more fish. There are very many persons with most diverse backgrounds and points of view, who are attacking this problem, and the methods used are perhaps as diverse as are the individuals. We do not propose to give any survey of the various methods in use, nor do we claim to be presenting any particularly novel method. The scientific attack on this problem in Canada is to a considerable degree co-ordinated under the Biological Board of Canada by its Research Committee on Fish Culture, and we purpose speaking of this attack on the basis of our association with the working of this Committee, but modified by our individual point of view.

The true scientist is like the man from Missouri,—he takes nothing for granted. Inevitably, therefore, he considers that the hatching and planting of fish is not necessarily the only solution, or even the best solution, of the fishery problem. Although we do not consider it the most fundamental part of the attack on this problem, the study of the effectiveness of fish planting bulks largely in the work of the Biological Board and, owing to its direct relation to current practice, creates the greatest interest. The subject might have been followed up in time-honoured fashion by devising means of planting more fish or larger fish, by collecting and analyzing statistics, or by hearing and sifting the evidence of persons with experience in the fashion of Commissions. None of these methods was adopted, but the course was chosen of finding out by experiment what were the actual results of planting fish in the current fashion. Facts of this nature, when sufficiently verified by repetition, could form the basis for making any changes in method that might seem desirable.

Dr. A. P. Knight, formerly Chairman of the Biological Board, was instrumental in initiating experiments on the effectiveness of the planting of trout fry in streams in eastern Canada, which have been carried out by Mr. H. C. White. A very high mortality of the fry during the first summer after planting was found in certain streams in southwestern Ontario and in Prince Edward Island. How general such mortality is must still be demonstrated, since there are as yet no results for cool, rocky, shaded streams. These latter are, however, less accessible for planting and less able to support large numbers of trout. There remains also the need for ascertaining the mortality under comparable conditions of naturally hatched fry. Mr. White has subsequently investigated the comparative mortality of various concentrations of planted trout fry, and has attempted to determine to what extent other factors are responsible for the mortality, finding

that large fish are the chief enemies, and then birds, while a variety of other factors, not clearly defined as yet, such as shortage of food, and competition with other small fish, carry off very considerable numbers. Although the analysis of the causes of mortality is far from complete even in the one locality and for the one species of fish, the speckled or brook trout *Salvelinus fontinalis*, the further step is being taken of attempting to apply the knowledge gained in reducing the mortality among planted trout fry by excluding large fish and birds from the planted area. Whether the success that may be attained will justify the expense that will be involved, remains to be seen, but accurate data will be available, both as to reduced mortality and expense in material and labour. It will be evident that a direct attack is being made on the problem presented by the planting of fry in order to determine to what extent such planting is justifiable, and how it should be carried out, that is, what treatment, if any, should be given to the body of water both beforehand and subsequently, and in what way the planting should be carried out, so as to ensure the most satisfactory results. In brief we are merely securing accurate data for use in formulating rational planting procedure.

The first examination of the effectiveness of cultural practice has dealt with the speckled trout, the fish of greatest interest to the angler. The second fish to be dealt with has been one of the greatest interest to the commercial fisherman, namely the sockeye salmon of the Pacific coast. The experience and results obtained with the trout have had only very slight value for application to the salmon owing to the very considerable differences in the living conditions of the two species, the trout being for the most part confined to streams and migrating but little, while the sockeye salmon is a lake and sea form with an extensive migration during its life history. A thorough quantitative study throughout a considerable number of years is being made of the comparative effectiveness of natural reproduction and fish cultural procedure by Dr. R. E. Foerster at Cultus Lake, British Columbia. It has proven possible to determine accurately the numbers of (1) the spawning fish, (2) the young migrating to the sea after one or more years sojourn in the lake, and (3) the fish returning to spawn after one or more years sojourn in the sea. This has been a more difficult and expensive task than in the case of the trout, and the time involved in an experiment is much greater, amounting to four or more years. Important results have already been attained showing a considerably larger yield with fish cultural methods than when reproduction is left entirely to nature. Whether this superiority of man's artifice occurs regularly, and, if so, whether the enhancement of the fishery will be sufficient to justify the expenditure involved remain to be demonstrated, and so the experiments proceed. As in the former investigations, so also in this, data are being accumulated to form the basis of rational fish cultural practice. While incidentally knowledge of a fundamental nature concerning the living

conditions of the fish is being gained, the outstanding feature of these practical investigations is the direct attack that is being made on the problem of how to have more fish by determining to what extent we get more fish by current fish cultural practice.

As a rule fisheries investigation is carried on somewhat in the following fashion. A complaint of the fishing not being as good as it used to be serves as the starting point of an investigation to determine what should be done to restore virgin conditions. An effort is made to bring together all the available facts bearing upon the situation and to discover more, all to serve as the basis of a report, in which the problem is reviewed and recommendations made,—usually to the effect that there should be restrictions on the fishery. Another course is to artificially stock the depleted waters with fish in the hope that this action may improve conditions. Definite good may result, but usually the issue is uncertain, for there has not been sufficient knowledge. Is there not a better way? We have been advocating and attempting a direct, fundamental attack upon the fishery problem so as to answer the following questions. In what respect is nature deficient, if at all, in the particular case? Are there suitable artificial means of remedying the deficiency at a cost which is not prohibitive?

To answer the first question requires knowledge not only of the requirements of the particular fish, but also of the conditions existing in the waters in question. One might, however, spend years in studying both of these and still be little farther ahead. Is there a shorter way of reaching the root of the matter than merely undertaking such studies? We believe that there is, though every way is arduous and tedious. We are primarily concerned with those requirements of the fish that are apt to be lacking in nature. Let us then study the fish in nature and wherever we find the fish failing to reach full development and abundance attempt to ascertain the reasons ror the failure. We should engage in a study of the thanatology, that is, the causes of death, of the fish in nature. This means that we must begin our work by making wide observations in nature.

Let me illustrate this method by the use of extreme, and therefore clear, examples. The haddock is an abundant and important food fish of the Canadian Atlantic coast, but does not occur in Lake Ontario. You will probably not hesitate to ascribe this to the virtual absence of salt in the water of Lake Ontario, and to the need of the haddock for water containing a fair quantity of salt. Experiment with the eggs, the fry and the adults of the haddock promptly serves to substantiate this theory. The cod is the most generally abundant food fish along our Atlantic coast, but is never found in the Gulf of Mexico, and the obvious interpretation of these facts is that the cod cannot endure subtropical heat. There is no difficulty in proving that temperatures as high as those in the Gulf of Mexico are fatal to the codfish in all stages of its life history. These cases are so clear and extreme that possibly no one would seriously propose that an

attempt should be made to build up a haddock fishery in Lake Ontario or a cod fishery in the Gulf of Mexico. Nature may be deficient in these respects, but she makes up for this deficiency in other ways.

Artificial intervention is more likely to be feasible in less extreme cases. The oyster is of commercial importance in the Gulf of St. Lawrence and also south along the Atlantic coast to Florida, but does not occur in the Bay of Fundy, which occupies an intermediate position. Attempts have been made in the past to introduce it into that bay, but without success. It is now known that the oyster requires, at least for reproduction, a higher temperature than is to be found in the waters of the Bay of Fundy, and introduction is accordingly useless unless higher temperatures are provided. With headquarters on Richmond Bay, Prince Edward Island, an attack has been begun by Dr. A. W. H. Needler and associates on the problem presented by the oyster on the Canadian Atlantic coast. The requirements of the oyster are being studied in relation to the varied conditions occurring in the waters of that coast. It is hoped that a foundation will be laid for a rational system of oyster culture. Summer temperatures, winter temperatures, salinity, food, and enemies are directions in which nature may fail in part or wholly to meet the needs of the oyster, and devices must be sought to remedy the failures, wherever feasible.

The lobster ranges from the strait of Belle Isle to New Jersey. Bad years in the fishery led to the establishment of hatcheries along the coast, but these were later abandoned. A system of rearing the fry was developed in Rhode Island, and an attempt was made to apply this system in Canadian waters at the mouth of the Bay of Fundy, in which the lobster is relatively scarce. Not a single larva was brought through to the second stage. We were able to discover the reason for failure both in nature and in the rearing experiments. The waters of the bay are suitable for spawning, for development and hatching of the eggs, and for the growth of the adults, but are too low in temperature for the fry. The latter are somewhat pelagic, swimming steadily up in the water, while the adults for the most part crawl about or rest on the bottom. To keep up in the water the fry have to take almost as much exercise at 50°F. (approximately the temperature of the inshore waters of the Bay of Fundy) as at higher temperatures, while their ability to take and digest food is much reduced. Consequently they die from starvation. If it can be accomplished economically, artificial rearing of fry at higher temperatures will provide a very definite means of increasing the lobster population of the Bay of Fundy, which is now kept up mainly by slow immigration, there being only two small areas where natural breeding is successful to a limited degree as the result of slightly higher temperatures than elsewhere. The nature of the population on each part of the coast is being determined and the conditions surveyed, so that measures may be recommended to suit the local conditions in

the direction either of regulation of the fishery or of the adoption of cultural procedure, if such proves practicable.

Each fishery, when surveyed, furnishes a series of questions, which must be answered before we can deal intelligently with the problem, and as yet, except in a few cases, we do not even know what the questions are, let alone the answers to them. Why is the smelt so abundant in the estuaries of northern New Brunswick and relatively so scarce in the southern part of that province? Why are there relatively so many more salmon in the larger river systems than in the smaller, and why are they so much more abundant some years than others? Why did they disappear from Lake Ontario? Why is the mouth of the Bay of Fundy so exceptionally rich in fishes and the head of the bay so poor? Why is Hudson Bay so barren and the waters of northern Europe in the same latitude so rich?

The latter questions lead us to the matter of a general attack upon the whole fishery problem rather than upon that presented by a particular fishery. It is more important that there should be valuable fish in each body of water rather than any particular species. We need to know the proper conditions for a valuable fishery and also how to assure those conditions. For example, shallow lakes seem to be more productive than deep lakes. Is this the case, and, if so, why? We have a theory, but it requires testing. We urge the following plan for the general attack on the productivity problem. In the first place a survey should be made of as diverse types of natural waters as are readily available and the relations established between particular types and the presence and abundance of particular species of fishes or other important organisms. Theories should then be developed to explain the correlations observed. These theories may then be tested by accurately controlled experiments. In many cases, however, it will be valuable to develop desired contrasts under semi-natural conditions in order to partly test out theories and to develop further correlations. Finally, however, all theories should be put to the test of rigid laboratory experiments, and from these the way followed by gradual steps to the complicated and costly practical experiment. It will perhaps immediately be evident that many, quite diverse types of work or investigation are required in this plan, for which may be required scientists with very diverse training and outlook. The old type of observational biology is not sufficient, though of primary importance. Associated with it there need to be ecology, physiology, biochemistry, chemistry, and physics. Every effort should be made to awaken the interest, and enlist the services, of specialists in these fields. Also constantly the investigations should be started from the standpoint of application to the needs of the fishery, and then the application should be more or less relegated to the background so that each investigation may be fundamental and thorough.

In the maritime provinces of Canada we have started with the

knowledge that some of the fresh waters are quite rich, while others are barren. We are studying and comparing these types. This is observation of nature. Richness in fish has something to do with the presence of fertilizing substances in the water, so we are developing contrasts in similar ponds placed side by side and exposed to the same climatic conditions, by using small as well as very large quantities of fertilizers, such as barnyard manure, sea mussels, and fish meal, and we watch the development of most diverse conditions throughout a period of years. A great variety of correlations are coming to light, many theories are being formulated, and to test these various rigidly controlled experiments are being planned. We are not, however, postponing indefinitely the practical experiment. One of our most accessible lakes is being fertilized with sea mussels and the result followed. Experiments having to do directly with the use of fish meal in the fertilization of lakes are in progress, and application is planned for next year. In this way, by attacking the problem simultaneously in a great variety of ways ranging from simple observation to practical experiment and with the interest and co-operation of the various types of scientists from biologists to physicists that carry on investigations at our stations, we may not follow the most ideal route from the scientific standpoint, but we hope to make rapid progress on fundamentally sound lines.

Discussion

Mr. Titcomb: I am sure we shall all benefit by the investigations by the Biological Board of Canada. Dr. Huntsman may be interested to know that in Connecticut we are rearing lobsters in boxes and that we are getting about ten per cent up to the diving stage, which is a little better than has been done at Wickford, Rhode Island. We got the suggestion as to our method from Norway, where a trough was used for carrying the lobsters up to the diving stage. These boxes are about fourteen inches square and the water which is discharged through perforated cylinders at the bottom of the box keeps the little cannibalistic creatures in motion so that they do not get at each other readily. We are so much encouraged that we are going to enlarge our equipment next year.

With reference to the smelt, if Dr. Huntsman wants to follow the methods of fish culturists he will find that he can propagate millions of smelt at a small cost. The smelt fry are ready to reproduce in two years.

Dr. Field: In 1896, when I was at the Rhode Island Agricultural Experiment Station, I conceived the idea that the fertilization of the water would increase the growth of diatoms and other plants upon which the oysters feed. We used commercial fertilizers as well as sewage of the town of Wakefield, Rhode Island. It is a matter which is worthy of investigation, to show that the nitrates and the nitrites would increase the growth of diatoms and plants. At Brockton, Massachusetts, the sewage effluent which flowed into the Cowesett River increased the growth of all manner of plants suitable for food for fish and birds.

ONTARIO FISHERIES RESEARCH LABORATORY

William J. K. Harkness

University of Toronto

During the five years previous to 1919 there was practically no fresh-water fisheries investigation carried on in Ontario.

In 1919 there was organized within the Department of Biology under Professor B. A. Bensley of the University of Toronto, a research branch devoted to the investigation of the water areas of Ontario with reference to existing biological conditions and economic problems. The title assigned to this branch was the "Ontario Fisheries Research Laboratory." The initial step in the organization was the appointment of Professor W. A. Clemens as Limnobiologist to take charge of field operations and to carry on continuous investigation of the material and data collected.

The work of the laboratory may be summed up as research of factors regulating the abundance and distribution of fish life in our waters, training of students in methods, principles and application of limnobiology, and the dissemination to the general public of information of such a nature as will show the way and demonstrate the need for conservation of our water resources and the life contained therein.

The plankton, which is so fundamental to fish life, has been a subject for continuous study. Plankton of the open water at all depths, of protected bays, among aquatic plants, in the mouths and along the courses of streams, has been investigated from both the qualitative and quantitative point of view. Considerable effort has been made to determine the seasonal variation in the plankton and the effect upon it of depth, temperature, light and association with higher aquatic plants.

Bottom organisms have been dredged from all depths of the lakes and streams studied, and from the data so obtained estimates have been made of the total bottom crop available as fish food, and the seasonal and annual variation of this crop. As the bottom-living animals feed upon the plankton, and as both are affected by pollution and various other factors, a field for investigation has been opened up, the surface of which is as yet barely scratched.

The fish themselves, which are of course more immediately important from an economic point of view, receive the greatest attention. A determined effort has been put forth to ascertain the species in each body of water, and the relative abundance of each species. Following the systematic study of the fish, special attention has been given to their relation to the plankton and bottom organisms, which they utilize as food, to the relation of the carnivorous fish and the smaller fish as enemy and food, the place of the minnows and plankton feeding fish as forage fish for the game fish, and the competition

of the suckers, ling and other generally less valuable fish with the valuable game and commercial species.

The chemo-physical analysis of the water has been carried or in conjunction with the other work so that correlation between temperature, oxygen, carbon dioxide, pH and total solids and the living organisms may be determined.

In addition to this comprehensive study it has been the object of the laboratory to develop an intensive investigation of the life history of our more important commercial and game fish.

The most complete and valuable life history study prosecuted by the laboratory is that of the whitefish by Dr. J. L. Hart. Dr. Hart carried on this study for over five years, placing special attention upon the spawning, hatching and early stages in the development of the fry, which he followed through much more completely than has been done heretofore.

Dr. Pritchard's study of the life history of the ciscoes of Lake Ontario was complicated by the presence of several closely related species and geographic races. Here again the early life history of one species was given special attention.

Similar intensive work on the speckled trout and small-mouthed black bass is now under way and should produce valuable data for cultural and conservational work.

It has not been the policy of the laboratory to investigate large numbers of lakes and streams, but rather to choose types and to investigate each type as thoroughly as possible in an endeavour to determine the principles underlying fish production.

Lake Nipigon, a practically virgin lake, was studied first over a period of seven years. Following this, Lake Simcoe, which has been fished commercially and for sport for almost one hundred years, was studied. At present the laboratory is located on Lake Nipissing. Lake Nipissing contains goodly numbers of valuable game and commercial fish, and it has been the seat of lumbering operations for forty-five years, so that there is considerable pollution due to sawdust bark and sulphite.

Concurrently with these three major investigations, comparative studies have been prosecuted on Lake Erie, Lake Abitibi, Long Lac, Trent Valley lakes, Georgian Bay and finally Lake Ontario where the major part of the cisco and whitefish life history work was carried on.

The speckled trout studies have been confined to the streams and smaller lakes of southern Ontario.

At the conclusion of each study scientific and semipopular papers are prepared. These are published in part in the various scientific periodicals but mostly in the Publications of the Ontario Fisheries Research Laboratory as part of the Biological Series of the University of Toronto Studies.

As a unit of the Department of Biology of the University of Toron-

to, the Ontario Fisheries Research Laboratory is a training laboratory as well as a research laboratory.

Men from biological courses are taken into the field during their undergraduate period. For the first two or three years these men assist with all phases of the general investigation and they voluntarily choose or are directed to a special line of endeavour. This they carry as graduate students, working out their problems and preparing papers on the results. These papers on their original investigations are submitted as part of the requirements for their graduate degrees. During the academic term there is continuous laboratory research on the material and data collected during the summer and with experimental problems. In conjunction with this research there are seminars and a course in Hydrobiology dealing with many phases of Marine and Freshwater biology. This course is given by specialists, but the students are given an opportunity of presenting their results and theories, and open discussion is the order of the day.

Professor W. A. Clemens was in charge of the organization and direction of the laboratory for the first three years. He is now Director of the Pacific Biological Station of the Biological Board of Canada.

During the last ten years a number of men have received a portion or all of their graduate training with the Ontario Fisheries Research Laboratory.

Dr. F. B. Adamstone is now at the University of Illinois.

Dr. A. E. Berry is with the Department of Public Health, Toronto.

Dr. R. E. Foerster is carrying on sockeye salmon investigations in British Columbia for the Biological Board of Canada.

Mr. H. H. MacKay is Biologist and Director of the Fish Culture Branch, Department of Game and Fisheries, Ontario.

Dr. J. L. Hart is investigating the pilchards for the Biological Board of Canada.

Dr. A. L. Pritchard is working on the pink and chum salmon of British Columbia for the Biological Board of Canada.

Professor J. R. Dymond of the Department of Biology of the University of Toronto has taken an active part in both the investigations and the training of students from the inception of the laboratory.

One of the immediate aims of the laboratory has been to pave the way for conservation, and by this is meant the full but proper utilization of our water resources.

Conservation is based on knowledge; knowledge of the complete life history, food requirements, and optimum living conditions of the organisms or organisms under consideration; knowledge which must be possessed by those in administrative capacity and by all others who are casually or constantly in contact with the organism either in the capacity of protecting it or destroying it for sport or commercial purposes.

It has at all times been one of the objectives of the laboratory to

place before the public as much information as possible of an educational and conservational nature. This has been accomplished in several ways. From time to time short newspaper announcements have been made of the progress of work. Extension lectures with moving pictures and lantern slides have been given throughout the Province. A contact has been established with the sporting fraternity. Short addresses have been given from time to time to local angling associations and those in more distant centres, keeping them in touch with the activities of our laboratory and the results obtained.

The Ontario Fisheries Research Laboratory has enjoyed the closest co-operation with and has received a great deal of assistance from the Department of Game and Fisheries of the Ontario Government, the Biological Board of Canada, the Research Council of Canada, the Anglers' Associations of Ontario, private individuals, mostly sportsmen, and biologists of the universities of the United States and Canada.

Discussion

Dr. Emmeline Moore: Certainly the work of the Research Laboratory at Toronto is deserving of high praise. Those of us who are interested in this type of work and know what it means to change the traditions, as it were, of a laboratory, can realize what an amount of effort and thought must have been put into the work described by Professor Harkness. It has been very interesting to note the extent to which the apparatus has been standardized so that results in different quarters are comparable, and in that respect we see the influence of Birge and Juday. For instance, the Ekman dredge, the Negretti and Zambra thermometer, the plankton equipment, etc., are helping us to understand each other's problems. Personally I congratulate the university in so quickly establishing in its laboratory such active and promising work.

FISHERY RESEARCH IN MICHIGAN

CARL L. HUBBS

Institute for Fisheries Research, University of Michigan

It is a strenuous problem with which we all are faced: to maintain and if possible to increase our game fish population, in the face of an ever increasing tendency toward depletion. This problem is a challenge to the energy and ingenuity of the peoples of North America. Its successful solution will take all we can put into it.

Two main forces can be brought into play to stem, and we hope eventually to turn back, this tide of depletion. One of these forces is a vigorous and intelligent administration of the inland fisheries. By this I mean of course the passing of wise fishing regulations, and their proper enforcement; extensive activity in artificial and semi-artificial propagation; the protection of spawning grounds and nursery waters, where desirable, and the modification of natural waters in one way or another so as to increase their productivity.

The second force which needs be brought into action to stem or turn back the tide of depletion of our fish supply is scientific investigation. In the great movements now under way to conserve and develop the fisheries, investigation is playing a prominent part. This is true the world around—I have seen the recent developments of the field of fishery research in lands as far away as Java and Japan. It is becoming generally recognized that fishery research is fundamental to sound and effective fishery administration.

Fishery research, like any science, has no political boundaries. Nevertheless each government needs maintain a scientific fisheries staff: firstly, to carry as good sports a share in this necessary work; secondly, to appreciate the scientific results obtained elsewhere in like investigations; thirdly, to adapt the results to local conditions; fourthly, to carry on investigations in fields which are of peculiarly local significance; fifthly, to train men to carry on the fishery investigations of the future, toward which we must increasingly turn our eyes; and sixthly, to help train future administrators, that they may effectively carry out and practically apply the results of the investigation.

Realizing these circumstances, Michigan is following the general tendency toward an increase in fishery research. Some time after the tragic and serious loss of Dr. Jan Metzelaar, the Michigan Department of Conservation inquired of the University of Michigan whether it would be willing to carry on for the Department the fishery investigations within the State. The University agreed to do this. Before I go on with a discussion of the organization of our fish research service, I feel constrained to pause long enough to pay tribute to the man I have just mentioned, and whom many of you knew.

To America, as a land of promise and opportunity, Dr. Jan Metzelaar came in November of 1923. Almost immediately he entered

upon his duties as Fisheries Expert for the Michigan Department of Conservation. From the first, his headquarters were maintained in the Division of Fisheries at the University. Metzelaar became fondly attached to this land he had adopted, and was made supremely happy by being admitted as a citizen of the United States on October 2, 1929. Just two days later he was drowned in Grand Lake, near Alpena. He died on duty, while carrying on his fish investigations. Thus, before the end of his thirty-eighth year, Jan Metzelaar joined the heroic band of martyrs to his science. This man, whose life was so tragically cut short, was born in the Netherlands on October 21, 1891, and he received a thorough education, ending in special training in ichthyology and fishery biology. After coming to America, Metzelaar carried on as his chief occupation, his duties as State Fisheries Expert. In this work he was fired by a tremendous enthusiasm, so real that no one could doubt his sincerity. He was staunchly loyal to his friends, and to the state departments with which he was connected; and even-tempered and generous toward the rivals and opponents which the nature of his official work unavoidably engendered; that indeed is a high tribute to the character of the man. He was ever ardent as a conservationist, and painfully disturbed at the way we Americans almost ruthlessly destroy our natural resources.

Metzelaar's activities were many. So pressing was the call for hundreds of minor investigations, and so limited the staff—a general curse in fisheries biology—that most of his work cannot be classed as major projects. He vigorously and successfully carried along the intensive survey of hundreds of trout streams of Michigan, with a view toward better policies and programs for replenishing the trout supply, and during the last two or three years, he similarly contributed to the fisheries survey of the inland lakes—a work on which he was engaged when he met his untimely death. He also made investigations on problems in trout propagation, such as the control by diet of goiter in hatchery trout. His very thorough studies of the food of the three species of stream trout in the state, and of their competitive inter-relations, have attracted very favorable attention. Many returns are now coming in from his extensive trout-tagging experiments, which are giving us evidence of the migrations of these fishes. Metzelaar's other investigations dealt with the status of the smelt in our waters, the proper conditions for wall-eyes; the growth of that species, and the difficulties encountered in its artificial propagation and conservation; the food of other species than trout; the time of spawning of game fish in reference to the open season, and the improvement of trout streams by the introduction of snags. Metzelaar did his work well, under many difficulties, and laid a foundation for us to build on.

A second fish investigator until recently with the Department of Conservation, T. H. Langlois, has now become the state superintendent of fish culture for Ohio. He also was located at the University

in which he had been trained, and he also gave good service to the state.

A third fish investigator, Dr. Walter Koelz, formerly of the Bureau of Fisheries, also a product of the University of Michigan, was employed by the Department of Conservation just before the University agreed to take over this field of work. He joined the fishery staff of the University but soon left to take an important post as a biological explorer in upper India.

It has become necessary for us, therefore, to build up a new staff of fishery investigators. This is a handicap to us at the start, but we expect to develop gradually an efficient and effective organization. To the position of fish pathologist we have appointed Wendell H. Krull. As assistant to the Director we have taken over Dr. John R. Greeley, well known for his work in the New York Biological Survey. As assistants and fellows we have eight young men of promise.

To care for this work the University of Michigan has established a new unit, known as The Institute for Fisheries Research, of which it is my lot to serve as Director during the period of organization. This department is financed largely by the Michigan Department of Conservation, with a very substantial additional subsidy from The Michigan Division of the Izaak Walton League of America.

The location of the Institute at the University of Michigan has a number of distinct advantages. It gives us the advantages of good laboratory and library facilities, of experimental aquaria, of a group of specialists ready to help us in their particular lines of work, as fish parasitology for example. And it gives us the advantage of obtaining student assistants, who are being trained to further the same line of work. And it further gives us the advantages of association with the Great Lakes Laboratory of the Bureau of Fisheries, which is housed in adjacent rooms, and which under Dr. Van Oosten is carrying on the investigations of the commercial fisheries in the Great Lakes.

We are attempting to initiate an enlarged fisheries research program in Michigan. A hasty summary of the present main activities of the Michigan Institute for Fisheries Research may be of some interest to members of the American Fisheries Society.

(1) *Creel census.*—For nearly four years the Michigan Department of Conservation has been obtaining records from fishermen of their catch-number of legal size fish of each species caught, number of fish below legal size caught and thrown back, number of hours fishing, etc. We obtain not a census of the total fish catch, but a measure of intensity, as fish caught per hour of sport fishing. This year the number of records is being greatly increased over the ten thousand obtained the previous year. The Institute is analyzing these statistics.

(2) *Lake and stream survey.*—The inventory of Michigan lakes and streams, with special reference to fish population, fish and fishing

conditions, and possible improvements in fish management, is being extended and intensified this year. This is particularly true of the lake work, thanks to the splendid co-operation of the Michigan Division of the Izaak Walton League of America. The League has provided fellowships in the University for three men being trained in problems of the development of the inland lake sport fisheries. These men, Eschmeyer, Ashley and Jones, this summer began their work by mapping and studying in detail all the lakes of Kalkaska County, Michigan.

(3) *Modifying conditions in natural waters.*—One of the great hopes of the Institute is to test out the practicability of modifying natural conditions so as to make for a greater fish yield. Places are underway for experiments in increasing weed beds on barren bottom, in introducing gravel spawning beds where deficient and in resnagging trout streams. The problem of introducing current-modifying barriers in trout streams is being actively carried on this summer, by Clarence Tarzwell. We are finding that it is by such means possible to improve trout conditions by increasing the number of holes in which trout find their homes, by increasing the shelter which will serve to protect them, by increasing the riffle areas in which trout love to feed, by increasing the weed beds so productive of trout food and so needed for the shelter of young trout. Each barrier placed now or in the last two years in the stream, as well as many natural barriers, are being copper-tagged, so that the permanence of the barriers and their effect on the stream may be followed from year to year.

(4) *Nursery waters.*—Studies are being made of the nursery waters of various species, with the points in mind of finding the most suitable places to plant young fishes of different stages, and of determining the utility of closing nursery waters, especially feeder trout streams. Dr. Greeley has immediate charge of these studies.

(5) *Migration studies.*—Extensive studies of trout movements by the tagging method are being continued in Michigan. Especially striking is the evidence of the great wanderings of rainbow trout, and the sedentary habits over most of Michigan of the brook trout.

(6) *Predator studies.*—Chief stress is now being paid to the concluding of an investigation, by Canuto Manuel, of the relation of the common term to the commercial fishes and fisheries. The results of this study appear to be gratifyingly conclusive. Material is also being gathered for a study, by J. Clark Salyer, of many other fish predators, not only birds but also fishes, mammals and reptiles.

(7) *Fish diseases.*—The diseases of Michigan fishes, both in hatcheries and nature, are being studied by the Fish Pathologist, Wendell H. Krull. Particular attention is being given the study of the many bacterial diseases which we find to be the chief maladies causing mortality among our fishes. The end will always be kept in view of trying to determine means of preventing the diseases, as of more

importance than the nevertheless necessary search for methods of treating the diseases once they have become epidemic.

(8) *Fish survey.*—The general ichthyological survey of the state, a corollary of the lake and stream survey, is being continued as for years past. This work has already led to a number of refinements in the classification of our fishes and will eventually head into a general treatise on Michigan fishes. One study of a special group, the ciscoes, or coregonid fishes, of the inland lakes of Michigan and adjoining regions, was completed by Dr. Walter Koelz while serving as Ichthyologist of the Institute.

(9) *Dwarfing analysis.*—A study of the extremely important question as to the real meaning of the dwarfing of perch and other fish species has been begun. This study will be conducted by Samuel N. Jones

(10) *Growth investigations.*—Much material is being gathered for a study of the growth rate, age and size at maturity, relation of growth to different natural conditions, etc. Experimental studies have been made on forced over-winter growth, and on the formation of growth marks on the scales and on increased growth induced by hybridization in the sunfish family.

It is the intention of this new Institute for Fisheries Research to study those problems which have a possible practical application in sight, and to carry on the investigations on a sufficiently large scale to make the results of as immediate applicability as possible.

A METHOD OF QUANTITATIVE BOTTOM FAUNA AND FACULTATIVE PLANKTON STUDY EMPLOYED IN A YEAR'S STUDY OF SLOUGH BIOLOGY

Eugene W. Surber

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It has been demonstrated by numerous observations that bass very early begin to feed upon entomostraca, water boatmen, midge fly larvae and the larvae and nymphs of other aquatic insects. Their importance as food for small pond fishes has been the subject of many papers presented before this society.

In a paper read to the society last year by Dr. Wiebe of the United States Bureau of Fisheries he pointed out that fertilizers could be used to advantage in bringing about an increase in the quantity of plankton in the bass rearing ponds of the Fairport, Iowa, station.

The effects of the fertilizer were measured, biologically, by plankton sampling. Dr. Wiebe has noted in some unusual cases that he has obtained a relatively high production in number of bass per acre from ponds which did not show high plankton counts.

It is the purpose of this paper to show how the usual method of measuring fish food in experimental ponds by plankton sampling or qualitative collections may be supplemented by the use and manipulation of quantitative bottom sampling apparatus. The abundance of such common fish food organisms as midge fly and various beetle larvae, mayfly, dragonfly and damselfly nymphs, of course, cannot be measured by plankton sampling, which obtains only those small organisms that drift or swim about feebly in the water. There are forms of entomostraca, sometimes termed facultative planktons, which swim about immediately over the bottom and frequently rest on it. The most common of these in sloughs of the Upper Mississippi River bottoms are the ostracods, small entomostraca which appear like small bivalve mollusks possessed of a power to swim about very vigorously on occasion; *Cyclops* often appears in large numbers in decants from bottom samples, showing that they often feed near the bottom and probably come to rest on it. Such heavy bodied entomostraca as *Simocephalus*, *Eurycerus*, *Sida*, *Latona* are found there too. *Cyclops* and *Chydorus* frequently rest on the leaves of submerged aquatic plants.

Perhaps the chief reasons why quantitative bottom sampling apparatus has not been used extensively to supplement plankton studies in ponds or other bodies of water where fish food studies have been conducted are (1) that it takes too much time to sieve the mud and pick the organisms out of the debris, (2) many small organisms were lost eventually in the sieving process or their enumeration appeared impossible. We believe we have now overcome these difficulties. A half dozen bottom samples can be taken from a pond,

sieved and preserved in about the same length of time consumed for the same number of plankton samples.

In our work in the sloughs of the Upper Mississippi River bottoms we have used the Petersen bottom sampler for obtaining bottom samples from the sloughs in summer and the Ekman sampler for winter work. These pieces of limnological apparatus are in quite general use for bottom investigations. The Petersen bottom sampler was originally designed for the study of the bottom populations of the sea and is described by C. G. J. Petersen in a Report of the Danish Biological Station (Petersen, C. G. J., 1911, pp. 48–49). The Ekman sampler first used by Ekman (1911) was modified by Birge (1922). Both pieces of our apparatus were made by J. P. Foerst, machinist, Physics Department, University of Wisconsin, at Madison.

An objection to the Petersen sampler is its weight, which is about thirty-four pounds without attachable weights. Objections to its weight are offset to a certain extent by the size of the sample it takes and the fact that it will bring up a sample of almost any type of bottom excepting rock. The Ekman sampler is light, weighing only a few pounds, but sand hinders its operation. For winter use the Petersen sampler is objectionable because of its size, weight and the size of the hole that must be cut through the ice.

The manipulation of a bottom sample from the time the jaws close on the sample at the bottom until the animals inhabiting the area covered by the sampler are retrieved from the mud or debris is very important. Descriptions of these manipulations usually have been omitted in descriptions of methods.

In taking a bottom sample, the sampler is lowered, open to the bottom. On coming in contact with it, the lever (in the Petersen sampler) which holds the jaws apart trips automatically. The sampler with its sample was then pulled up over the stern of a boat and swung into a waiting tub, 17 inches in diameter,* in the same motion. Usually some small amount of mud and water was lost at this point. The dredge was emptied in the tub and adhering mud scraped or washed off with the water from the sample which was already in the tub. The task of getting as many of the animals in the mud and in the water over the mud was begun in the field while the organisms were still alive. It was usually noticeable that the water obtained in the bottom sampler contained many organisms; chiefly Ostracods, Cyclops, Hyalellas, damsel fly nymphs and other active organisms.

To secure these, the contents of the tub were thoroughly stirred and the sample allowed to settle for at least ten minutes. If a sample contained much mud and little water, sufficient water strained through a 150 mesh sieve was added to make the stirring of the sample easy. During the stirring process an opportunity is afforded

*A three gallon pail was used with the Ekman sampler.

for many of the organisms to escape from the mud and debris and swim about in the supernatant water.

As soon as the coarse material has settled to the bottom of the tub or pail, as the case may be, the supernatant water is poured through a No. 150 mesh brass soil sieve eight inches in diameter. The organisms thus captured are concentrated by sweeping the bottom of a sieve back and forth over a water surface then transferred to a large-mouth 8-oz. bottle. This portion of the sample, which wė call the "decant," is preserved by adding enough formaldehyde to make approximately an 8% solution.

The remainder of the sample, mud and debris is poured through a No. 30 mesh soil sieve. A 40 mesh sieve can be used where the bottom to be sampled does not contain much plant debris. The organisms and debris obtained in this final manipulation are concentrated by sweeping over a water surface as in the first manipulation and transferred to a pint jar to which enough formaldehyde is added making approximately a 10% solution. An "up and down" movement holding the sieve in the water close to the surface is required to free organisms and debris from silt. Mud adhering to the sides of the tub or pail may be freed with strained water and put through the final manipulation.

In samples containing coarse sand or gravel sieving was preceded by a process of repeated stirring (rotating the water) and decanting until all of the material had passed through or accumulated on the sieves with the exception of coarse sand or gravel which was finally discarded.

All vegetation brought up in the bottom samplers were deposited with samples and mud in the receptacle. Care was taken to wash as many of the organisms as possible from the leaves and stems of the plants. This was accomplished by sweeping the plants back and forth in the supernatant water over the mud in the sample. Plant fragments of sufficient length were placed in the collection jars so that identification could later be made.

In the laboratory the following procedure was followed in enumerating organisms in these samples.

The decants are shaken up thoroughly and about 15 c.c. quickly poured out into a graduate. After noting the volume, the portion was poured into a petri dish, 98 m.m. in diameter. This dish was marked off in 12 sectors with a diamond pencil similar to a bacteria counting cell. In one of the sectors an "X" was placed to mark a starting point for the count that followed. Counting was done on the raised stage of a binocular scope with the light coming from below.

The fraction which the portion enumerated constituted of the total volume of the decant was used as a factor in estimating the total number of organisms in the decant.

The abundance of organisms captured in the 30 mesh sieve (or 40 mesh, as originally used) was estimated in the following manner: If

the volume of debris was large, most of the supernatant water was poured off the debris in the pint jars (being careful not to pour off organisms buoyed on the surface film). The debris in a loose or half suspended condition is then stirred and a convenient portion (not less than 50 c.c.) was taken for enumeration. If only a fraction of a sample was used, a factor was again used to estimate the number of organisms in the debris after the total amount of it had been determined. Enumeration of the organisms was performed in a petri dish as described above with the aid of a binocular scope with a raised stage with the light coming from below (an important point).

The writer is not at all satisfied that the apparatus used in a year's study of the bottom fauna of sloughs in the upper Mississippi River bottoms is the best that can be designed for this work. Reinsch (1924, p. 255) describes a piece of apparatus for collecting in vegetation that certainly excels the Petersen or Ekman samplers in scientific principle for collecting facultative plankton organisms or organisms that dwell on or near the bottom. However, this apparatus appears to be too complicated to handle in ordinary field work.

It is one of the purposes of this paper to call attention to the need which exists for a piece of apparatus that is nearly scientifically irreproachable and at the same time easily manageable.

The organisms which occur frequently in the decants from the bottom samples have often appeared in large numbers in the intestines of small slough fishes, which indicates that their evaluation in quantitative terms is of great importance. In fact, it appears from recent studies that they are more important than the organisms which dwell in the bottom materials. Baker (1918, pages 133–190) found Cladocera in bottom samples taken in Oneida Lake of the same genera and species which occur in the bottom samples of the sloughs. He says, "These small animals are of great value as food for the young of large fish and of small fish, many of which were observed browsing on the Algae which contained these minute forms of life."

Adamstone and Harkness (1923, p. 127) observed that very few specimens of Cladocera were obtained in their bottom samples. "This was due most probably," they say, "to the fact that they were usually lost, on account of their small size, in the process of washing and cleaning the material. This was unfortunate especially since some of these forms are important constituents in the food of bottom feeding fish." They have also observed "that examination of fish stomachs showed that in some localities Ostracoda must be extremely abundant and form a very high percentage of the stomach contents."

The following tables are presented to illustrate the magnitude of bottom and wood fauna populations in sloughs of the upper Mississippi River. Tables Nos. 1 and 2 were compiled from collections in 1928 before I had adopted the present method of decanting. At that time a No. 40 mesh sieve was used, but all of the material, with a few exceptions, which was brought up by the sampler went through

it. All of the debris retained in the sieve was searched through thoroughly by examining small portions of the material at a time in a petri dish on the raised stage of a binocular scope. Table No. 3 has just been compiled to illustrate results obtained by the method now employed. Attention is called to the large number of Copepods and Ostracods occurring in the "decants".

TABLE 1

Average Number of Bottom and Plant Dwelling Organisms Per Square Meter and Frequencies of Their Occurrence in 41 Bottom Samples Taken Mostly in Sloughs of the Upper Mississippi Wild Life and Fish Refuge.

		Frequency of occurrence of 1 or more organisms of each kind in 41 samples	Average No. of organisms per square meter
Coelenterata:	Hydra	14	54.57
Platyhelmia:	Planaria	18	447.14
Nemathelmia:	Nematoda	39	998.41
Chaetopoda:	Oligochaeta	40	3,419.43
	Lumbricus	5	2.31
Hirudinea:	Leeches	27	65.48
Mollusca:	Planorbis	8	196.12
	Physa	9	138.24
	Campeloma	2	8.59
	Valvata	1	.99
	Pisidium	5	6.94
	Musculium	15	60.85
	Mussels, Juv.	7	35.58
Crustacea:			
Cladocera:	Sida	2	1.32
	Latona	2	7.60
	Diaphanosoma	5	4.63
	Daphnia	8	19.18
	Simocephalus	16	17.19
	Moina	1	.33
	Ceriodaphnia	5	19.84
	Bosmina	1	.33
	Eurycercus	11	69.12
	Camptocercus	1	4.96
	Alona	10	14.88
	Chydorus	3	1.32
	Unknown	3	2.97
Copepoda:	Diaptomus	9	7.27
	Cyclops	39	730.56
	Canthocamptus	16	77.39
Ostracoda:		41	6,455.67
Amphipoda:	Hyalella	31	979.75
Isopoda:	Asellus	22	226.88
Arachnida:	Spiders	11	3.96
Hydrachnida:	Mites	21	43.65
Collembola:	Spring-tails	2	.99
Plecoptera:			

TABLE 1—*Continued*

Average Number of Bottom and Plant Dwelling Organisms Per Square Meter and Frequencies of Their Occurrence in 41 Bottom Samples Taken Mostly in Sloughs of the Upper Mississippi Wild Life and Fish Refuge.

		Frequency of occurrence of 1 or more organisms of each kind in 41 samples	Average No. of organisms per sqaure meter
Ephemerida:	(Nymphs)		
	Hexagenia	19	31.74
	Heptagenia	2	.66
	Ephemerella	2	1.65
	Caenis	19	103.84
	Callibaetis	2	.99
Odonata:	Anisoptera (nymphs)	10	7.60
	Zygoptera	22	183.22
Hemiptera:	Corixidae		
	Corixidae (nymphs)	23	85.32
	Belostoma	3	7.27
	Plea (nymphs)	17	40.34
Neuroptera:	Sialis larvae	4	2.97
Trichoptera:	Larvae	21	49.60
Coleoptera:	Larvae		
	Haliplidae	20	108.48
	Dytiscidae	4	5.62
	Gyrinus	4	9.26
	Dineutes	1	.33
	Laccophilus	1	.33
	Berosus	8	10.58
	Unknown	11	10.58
Diptera:	Corethridae (larvae)	11	56.88
	Corethridae (pupae)		
	Ceratopogoninae (larvae)	31	96.24
	Chironomidae (larvae)	31	2,327.51
	Chironomidae (pupae)	23	
	Dipterous (pupae)	10	9.59
Miscellaneous:			
	Terrestrial insects		
	Cysts		
	Unknown		

TABLE 2

A Comparison of the Average Number of Organisms per Square Meter on Areas of Slough Bottoms which support larger Aquatic Plants with those which do not.

		Distance from shore: C–15′ (inclusive) Vegetation present Av. No. of organisms per sq. meter (15 samples)	Distance from shore: C–15′ (inclusive) Vegetation absent Av. No. of organisms per sq. meter (11 samples)
Coelenterata:	Hydra	103.96	6.16
Platyhelmia:	Planaria	292.89	1.23
Nemathelmia:	Nematoda	1,312.41	101.08
Chaetopoda:	Oligochaeta	4,541.69	1,206.84
	Lumbricus	3.61	1.23
Hirudinea:	Leeches	1,175.20	7.39
Mollusca:	Planorbis	1.80	3.69
	Physa	4.52	1.23
	Campeloma	23.50	0.00
	Valvata	0.00	0.00
	Pisidium	7.23	16.02
	Musculium	96.72	62.86
	Mussels, Juv.	11.75	0.00
Cladocera:	Sida	3.61	0.00
	Latona	.90	27.12
	Diaphanosoma	9.04	2.46
	Daphnia	19.88	8.62
	Simocephalus	30.73	2.46
	Moina	0.00	0.00
	Ceriodaphnia	40.68	0.00
	Bosmina	0.00	1.23
	Eurycercus	141.92	9.86
	Camptocercus	0.00	0.00
	Alona	16.27	18.49
	Chydorus	2.71	1.23
	Unknown	0.00	2.46
Copepoda:	Diaptomus	4.52	8.62
	Cyclops	1,010.61	711.28
	Canthocamptus	204.30	3.69
Ostracoda:		3,281.52	632.06
Amphipoda:	Hyalella	2,042.47	81.36
Isopoda:	Asellus	475.50	13.56
Arachnida:	Spiders	4.52	2.46
Hydrachnida:	Mites	940.16	1.23
Collembola:	Spring-tails	.90	2.46
Ephemerida:	Hexagenia	25.31	13.56
	Heptagenia	.90	0.00
	Ephemerella	4.52	0.00
	Caenis	94.92	18.49
	Callibaetis	2.71	0.00
Odonata:	Anisoptera (nymphs)	17.17	0.00
	Zygoptera	435.72	8.62
Hemiptera:	Mostly nymphs	106.67	39.44
	Belostoma	18.98	0.00
	Plea (nymphs)	54.24	6.16

TABLE NO. 2—*Continued*

A Comparison of the Average Number of Organisms per Square Meter on Areas of Slough Bottoms which support larger Aquatic Plants with those which do not.

		Distance from shore C–15′ (inclusive) Vegetation Present Av. No. of Organisms per sq. meter (15 samples)	Distance from shore C–15′ (inclusive) Vegetation Absent Av. No. of Organisms per sq. meter (11 samples)
Neuroptera:	Sialis larvae	6.32	0.00
Trichoptera:	Larvae	96.72	8.62
Coleoptera:	Haliplidae	187.12	6.16
	Dytiscidae	11.75	0.00
	Gyrinus	18.08	0.00
	Dineutes	.90	0.00
	Laccophilus	0.00	0.00
	Berosus	14.46	0.00
	Unknown	8.13	7.39
Diptera:	Corethridae (larvae)	59.66	14.79
	Ceratopogoninae (larvae)	91.30	188.60
	Chironomidae (larvae)	4,132.18	1,478.04
	Dipterous pupae (?)	12.65	1.23
		Distance from shore 15–60′	
		(7 *samples*)	(8 *samples*)
Coelenterata:	Hydra	87.17	
Platyhelmia:	Planaria	216.96	1,550.92
Nemathelmia:	Nematoda	280.89	2,271.31
Chaetopoda:	Oligochaeta	1,911.96	5,676.55
	Lumbricus	1.93	1.69
Hirudinea:	Leeches	60.05	52.54
Mollusca:	Planorbis	1,133.22	5.08
	Physa	794.22	3.39
	Campeloma	0.00	0.00
	Valvata	5.81	0.00
	Pisidium	15.49	22.03
	Musculium	5.81	38.98
	Mussels, Juv.	50.36	115.25
Cladocera:	Sida	0.00	0.00
	Latona	0.00	0.00
	Diaphanosoma	1.93	1.69
	Daphnia	38.74	15.25
	Simocephalus	23.24	6.78
	Moina	0.00	1.69
	Ceriodaphnia	0.00	25.42
	Bosmina	0.00	0.00
	Eurycercus	81.36	3.39
	Camptocercus	29.05	0.00
	Alona	3.87	16.95
	Chydorus	0.00	0.00
	Unknown	9.68	3.39
Copepoda:	Diaptomus	11.62	6.78
	Cyclops	468.78	461.04
	Canthocamptus	00.00	8.47
Ostracoda:		26,237.78	3,105.32
Amphipoda:	Hyalella	1,084.80	130.51

TABLE No. 2—*Continued*

A Comparison of the Average Number of Organisms per Square Meter on Areas of Slough Bottoms which support larger Aquatic Plants with those which do not

		Distance from shore 15–60) (inclusive) Vegetation Present Av. No. of Organisms per sq. meter (7 samples)	Distance from shore 15–60' (inclusive) Vegetation Absent Av. No. of Organisms per sq. meter (8 samples)
Isopoda:	Asellus	110.41	155.94
Arachnida:	Spiders	5.81	3.39
Hydrachnida:	Mites	44.45	6.78
Collembola:	Spring-tails	0.00	00.00
Ephemerida:	Hexagenia	56.17	94.92
	Heptagenia	1.93	0.00
	Ephemerella	0.00	0.00
	Caenis	354.49	44.07
	Callibaetis	0.00	0.00
Odonata:	Anisoptera (nymphs)	5.81	1.69
	Zygoptera	122.04	3.39
Hemiptera:	Mostly nymphs	23.24	162.72
	Belostoma	0.00	1.69
	Plea nymphs	92.98	15.25
Neuroptera:	Sialis larvae	0.00	3.39
Trichoptera:	Larvae	58.11	10.17
Coleoptera:	Haliplidae	218.89	5.08
	Dytiscidae	7.74	0.00
	Gyrinus	15.49	0.00
	Dineutes	0.00	0.00
	Laccophilus	1.93	0.00
	Berosus	30.99	0.00
	Unknown	27.12	5.08
Diptera:	Corethridae (larvae)	25.18	137.29
	Ceratopogoninae (larvae)	38.74	28.81
	Chironomidae: (larvae)	352.12	935.64
	Dipterous pupae (?)	17.42	8.47

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TABLE NO. 3

Bottom Fauna of Franks Bay (Jack Slough) near Irempealeau, Wis., on Sept. 5, 1929. Population figures are numbers of organisms per sq. meter of bottom. A = decant; B = debris; S = shore; M = middle of slough

Sampling	Station	No. 1-S		2-S		3-M		4-S		5-S		6-M		Total	Total	Av. per Station
		A	B	A	B	A	B	A	B	A	B	A	B			
Coelenterata	Hydra			256											256	43
Platyhelmia	Planaria		13												13	2
Nemathelmia	Nematoda		27		39						40		13		119	19
Chaetopoda	Oligochaeta		488		797		867		1,305	176	569		854		5,056	843
Hirudinea	Leeches		27		108						13				148	24
Mollusca	Muscolium		1,030		1,315				93		745		393		3,576	596
Cladocera	Sida		13												13	2
	Eurycercus		13								13	223	27		276	46
	Alona				39										39	6
Copepoda	Cyclops	33,570		9,231	79	8,710		2,041		3,878		223	13		57,745	9,624
Ostracoda	Ostracods	91,243		115,388		80,688		40,321		87,963		113,436			529,039	88,173
Amphipoda	Hyalella				39		13								52	8
Isopoda	Asellus		40		39						13				92	15
Hydrachnida	Mites						108				13		13		134	22
Ephemerida	Hexagenia				39						54				93	15
	Caenis		13		119					176	13				321	53
Hemiptera	Corixa nymphs		13				13		93						119	19
Neuroptera	Sialis lv.		27								13				40	6
Trichoptera	Larvae				39										39	6
Coleoplera	Larvae															
	Haliplidae				39										39	6
	Berosus										27				27	1
Diptéra	Larvae															
	Corethridae	573	27		39	3,056	4,759		279	176	27	671	216		2,823	1,303
	Ceratopogoninae	286	501		398		461		559		366		284		2,855	476
	Chironomidae	6,312	1,057	4,615	3,269		108	1,531	1,772	2,467	1,613	2,908	3,796		29,448	4,908
	" pupae			94		518					13		195		820	136
	Tabanus lv.										27				27	4

Discussion

Mr. Detwiler (Ontario): In some of our rearing ponds we find that by the time the summer is well advanced the bottom is almost completely covered, for example, with Elodea in a dense mass, from three to four feet long. How would you get a quantitative analysis of the bottom fauna in a pond like that?

Mr. E. W. Surber: Of course where the vegetation is very dense the only piece of apparatus suitable for capturing organisms would be the Petersen bottom grab, which will go down and pick up the mud and plants over that area. You will not get the organisms which cling to the plants outside of the sample, but you will at least get some idea of the abundance of the organisms present.

Mr. Detwiler: But the jaws of the dredge simply fill with weeds and everything else runs out.

Mr. E. W. Surber: That is the weakness of our whole system of quantitative bottom fauna work. One of the purposes of this paper is to show that we need some kind of scientific apparatus which can be used for sampling when a large number of organisms are present. A German worker has devised a piece of apparatus for collecting organisms that live in and on vegetation, but it is not a practicable piece of apparatus to handle in ordinary quantitative work.

Mr. Detwiler: Then I should say your method could not be applied generally.

Mr. E. W. Surber: I would say it could not be applied to ponds filled densely with vegetation.

Mr. Detwiler: Rarely, then, because by July the ponds are pretty well grown over with a dense mass of vegetation.

Mr. E. W. Surber: Of course in our sloughs we have a different situation: a large amount of vegetation is found along the shore early in the summer, and there are large numbers of organisms as Chironomids in the middle of the pond away from the zone of vegetation, which we can easily get at with quantitative apparatus. Samples in the zone of vegetation are not of value except to give some idea of the abundance of the organisms. In the latter part of the summer the river recedes and the water level in the sloughs drops correspondingly, leaving behind a large mass of this vegetation to dry out on the shore.

Mr. Detwiler: How do you know whether the water is from the top of the bottom soil or from some other part of the water?

Mr. E. W. Surber: The organisms that you find in bottom samples are organisms that we know must have occurred in the water just over the bottom, because otherwise we would find them in our plankton samples.

Mr. Detwiler: Isn't your method too accurate for the margin of error that you have to meet? You take care of so many factors that you cannot evaluate all of them with accuracy. Since you cannot control all the factors, why resort to such an extremely refined method? Suppose you get a thousand forms of life to the litre, you cannot say that is the actual population down there.

Mr. E. W. Surber: In my work I tried to use quantitative methods as far as I could, because I realize that when you try to deal with absolute values you are going further than when you deal with just qualitative data. The Petersen and the Ekman samplers are considered standard apparatus, and the variability in the number of organisms in the samples from the same slough will show the need of apparatus that will give the scientist a true picture of the bottom organisms.

Prof. Harkness: In this type of work we do not take one sample from the bottom and make our quantitative estimate on that one sample. We take a large number of samples so that by taking the average we overcome the objection of too great accuracy. I think Mr. Surber's paper is very much to the point. Quantitative work in streams and lakes is in its infancy. In the course of the next twenty-five years the apparatus we are using at the present time will be entirely obsolete, because the more we work with it the more its inefficiency is demonstrable. As Mr. Surber says, every person is interested in trying to get some new apparatus that is scientifically accurate, but I do not think we shall ever be able to get an apparatus that can be used in every type of habitat. We are bound to develop different types of apparatus for pond, stream and lake.

In our analysis of the water we have been getting samples from close to the bottom, German investigators have pointed out that the life at and just above the bottom is so much more intense than higher up. There is probably a layer of water very close to the bottom about which we know practically nothing at the present time. It seems to me that the next important advance is the study of the layer just above the surface of the bottom. We are contemplating the construction of a suitable apparatus for this study next year.

Dr. Wiebe: In this connection it may be of interest to note that Professor Birge is carrying on experiments with the Petersen water sampler which has a number of compartments only a few inches in extent to determine this microstratification.

THE MARKETING OF LING (BURBOT)

Hugh Branion

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Some of the papers read at this meeting have emphasized the need for co-operation between various workers in different fields of scientific investigation in the fishing industry. This paper is an account of co-operative work by specialists in various branches of science. Biologists from the Ontario Fisheries' Research Laboratory, dietitians from the Department of Household Science, a biochemist from the Department of Biochemistry, all in the University of Toronto, chemists from the Biological Board of Canada, and a biochemist from the Ontario Research Foundation have worked together in co-operation with the Biological Section of the Fish Culture Branch of the Department of Game and Fisheries for Ontario.

The ling (*Lota maculosa*) is the only freshwater member of the cod family, all its relatives living in the sea. It probably has more common names than any other fish, being variously called ling, burbot, lawyer, eelpout, mother-of-eels, methy, dogfish, freshwater cod and lake cusk. Burbot is its correct name and it seems desirable for several reasons that it should come into general use.

Burbot is found in all the Great Lakes and is fairly well distributed in all the larger lakes of Canada and the northern United States. Throughout the year burbot is caught in marketable quantities in whitefish, herring and trout gill nets, as well as in pound nets and on night lines. There are no available statistics for the catch of burbot in Canada, since it is grouped with other fish under the general heading "coarse fish." In the United States the reputed catch is 500,000 pounds per year—in our Canadian waters this amount is undoubtedly exceeded. Burbot average from two to five pounds in weight, although specimens weighing ten pounds are not uncommon.

There is no market for burbot except in a few small local centres. These are too small to consume even an appreciable fraction of the catch. The fisherman is forced either to remove the fish from his nets and throw them back into the lake where they become carrion, or to take them to shore and bury them. It was evident some years ago that a method of utilizing burbot was necessary, for any one of several reasons. The burbot is a very heavy cannibal feeder and destroys untold quantities of commercial fish. Pike, perch, herring and ciscoes all fall victim to its voracious appetite. The burbot also eat alewives and compete with lake trout for food. As an example of their appetite, an examination of one stomach showed 39 sculpins, 6 alewives, 1 herring seven inches and 1 herring nine inches in length.

The burbot also have the disconcerting habit of visiting herring gill nets and either eating the herring caught in the net or else sucking off their scales and so spoiling the herring for marketing. Fishermen

have claimed that burbot follow the whitefish to their spawning grounds and devour the spawn. "To give the devil his due," in only one stomach from the hundreds examined has any spawn been found. The burbot causes a great deal of damage to gill nets at a season when fishing is precarious and time is most valuable. The fish has become so plentiful in Lake Ontario that, for the past few years, fishermen are extremely reluctant to place whitefish nets in the water, for it is almost a certainty that they will be ruined by burbot in a month's time.

In addition, it seems evident—although some of you will disagree—that the supply of what the public is pleased to term "fine" fish, namely herring, trout and whitefish, is being steadily depleted in most of the Great Lakes. If a market can be established for some of these lesser known, although equally palatable, fish, of which burbot is an outstanding example, it would give the commercial fish a chance to restock these waters naturally.

There are three possible ways in which burbot may be utilized, first as food, secondly as fish meal or as fertilizer, and thirdly there is the possibility of using its liver and liver oil. From an economic viewpoint the utilization of burbot as edible food is the most important. The qualities of this fish as food have been in dispute for years. Until recently the consensus of opinion in America has been against it. There is no doubt that popular prejudice has been built up against burbot because of its repulsive appearance. The fact remains, however, that the European burbot is considered a "delicately flavoured fish" with an excellent market. The liver and roe have always been considered delicacies. In the United States, through a campaign conducted by the Bureau of Fisheries, a market has been established. During the Great War burbot was to be found on the Canadian markets, but as soon as the scarcity of meat was alleviated no further attempt to continue the market was made.

In 1928 cooking experiments were conducted in the Department of Household Science of the University of Toronto by Miss Margaret Templin under the direction of Dr. A. Willard and the writer. Miss Templin reported that fried burbot was "quite palatable—tender, juicy and had a delicate flavour." Fish loaf made from boiled burbot was "just as edible as that made from cod." She also made fish cakes from burbot and reported that they had "a fresh delicate flavour and were as good as, or superior to, those made from cod." However, in view of its repulsive appearance she considered that burbot in its "natural" state could not be commercialized successfully, but "if it were filleted and sold under a trade name there is no reason why, through its fine flavour and texture, it should not become very popular."

Burbot was also sent to various homes in the city where several methods of cooking were used by the housewives, including baking, frying, broiling and steaming. In some cases the fish were filleted

and made into special dishes. All reported that the fish was very tasty.

There is also the possibility of creating a market for burbot livers. They are of large size, being about 10 per cent of the round weight of the fish. Excellent recipes for the canning and cooking of burbot livers served as soups, toasts, liver loaf and as fillings for tomatoes and so on, have been prepared by Dr. A. Marlatt of the Home Economics Department of the University of Wisconsin. Investigations into the effect of burbot livers in dietaries, with particular regard to pernicious anaemia, are being carried on in the Toronto General Hospital.

Miss Templin has shown that burbot roe is a delicacy. To quote her words, ". . . and this when placed on hot buttered toast and seasoned, seemed as attractive as any roe. Thus the roe of the burbot, which occurs in great abundance, might be used to as great an extent as any other."

This brought to an end what might be termed the experimental stage in the utilization of burbot. This summer, Mr. H. H. MacKay, Biologist and Director of the Fish Culture Branch of the Department of Game and Fisheries, made possible the next step—the utilization of burbot on a commercial basis. Realizing the importance of this problem and the necessity for government assistance in its continuation, he made it possible for the writer to make a survey of the available supply of burbot in the Great Lakes and to look into those local markets where burbot was sold, in an attempt to decide which method of handling is most feasible. At the same time the co-operation of the Great Lakes' fishermen in creating a market was obtained.

Burbot, cleaned and skinned, were supplied to various hotels and restaurants in Toronto. Their chefs were asked to cook these fish and to forward their opinions to the Department. The following quotation from one of these expressions of opinion will serve as an example of their conclusions: "The burbot which you sent me were excellent and compare very favourably with any fish which I have obtained from the wholesalers." It is obviously possible, therefore, to put burbot on the market as edible food. To avoid the disadvantage of its repulsive appearance it will be necessary to skin the fish, but this can be done easily and rapidly. A pamphlet containing a short account of the history of burbot and recipes for the serving of burbot as food is now being prepared. Plans for its marketing are being considered.

Other than the backbone, burbot is boneless and excellent fillets can be made from it. It can be salted as ocean cod is salted and is equally good. Burbot can also be pickled or preserved as "strip fish" and in some instances has been smoked successfully. Frozen fillets made by rapid brine freezing as developed by the Biological Board of Canada would be a means of preserving any surplus.

Fish meal was made from burbot by Mr. W. Stewart of the Atlantic

Fisheries' Experimental Station and on chemical analysis compared favourably with commercial fish meal. It seems safe to predict a movement for the manufacture of by-products, such as fish meal, in Great Lakes' fishing industry. This would be one method for disposal of burbot.

Since the burbot is a relative of the cod it was considered that the liver oil might serve medicinally as cod liver oil. The therapeutic effect of cod liver oil lies in its content of two fat-soluble vitamins A and D which are necessary for normal growth, for the formation of good teeth and bones and to aid the body to resist infection. The writer extracted oil from burbot livers by the direct steam method, which is now generally used in the manufacture of medicinal cod liver oil. The yield, colour and taste of the oil compare very favourably with cod liver oil. The vitamin A potency of the oil, tested biologically, is about 500 units per gram or better, and compares excellently with medicinal cod liver oil obtained in the open market. The vitamin D potency of burbot liver oil was also shown to be as good as, if not better than, medicinal cod liver oil. Dr. Marlatt, at about the same time, working at Wisconsin, reported that, "burbot liver oil may be classed with cod liver oil as an excellent source of the antirachitic vitamin."

Burbot liver oil was also shown to be capable of hydrogenation, or hardening, by Dr. A. Barbour of the Ontario Research Foundation. The iodine number of burbot liver oil was lowered from 175.5 to 4.6 in five hours, using 1 per cent by weight of nickel catalyst, hydrogen pressure being 25 pounds per sq. inch at 105° C.

The prospect for future marketing of burbot looks bright, and without doubt this fish can be turned into a source of profit to the fishermen. Its edible qualities can no longer be disputed, and as an added source of profit the liver oil might be manufactured while the liver itself may find a profitable market.

The Cinderella of the Fish World, despised because of its homely appearance, should take its proper place among the recognized profitable commercial fish.

(The writer wishes to express his appreciation to those workers who have co-operated and assisted him in this work. Thanks are also due to those fishermen of Lake Ontario who have supplied burbot for this research at no small inconvenience to themselves.)

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Discussion

Dr. Hubbs: We have made extensive studies of the food of the burbot in Saginaw Bay, Michigan, and have found it extremely destructive to food fishes. It seems to have a particular liking for whitefish and lake herring, yellow pike and perch, which are the main fish of that region. We can therefore confirm the statements which are made as to its extreme destructiveness. One burbot had taken 179 fish at one meal. On the basis of rough estimates of the abundance of the tern and the burbot we have come to the conclusion that the burbot must be at least two hundred times as destructive as the tern. The need for the marketing or disposal of the burbot also occurred to us and we trust that the work in Ontario will aid us. At the present time a large percent of the burbot are thrown back into the water to continue their depredations.

Dr. Van Oosten: How much of the Great Lakes territory was covered by your survey for determining the abundance of the burbot, and which regions are the centers of destruction or of greatest abundance?

Mr. Branion: We covered only Canadian waters, and so far we have not covered all. The only information I have with regard to the American waters is in the form of various communications sent me by Mr. Conn, of the Bureau of Fisheries.

Dr. Van Oosten: Where did you find burbot most abundant in Canadian waters?

Mr. Branion: It is most abundant in Lake Ontario; probably the most productive area is about fourteen miles west of Toronto, at Port Credit. They carry on winter fishing during the spawning months, January and February.

THE DISAPPEARANCE OF THE LAKE ERIE CISCO—A PRELIMINARY REPORT

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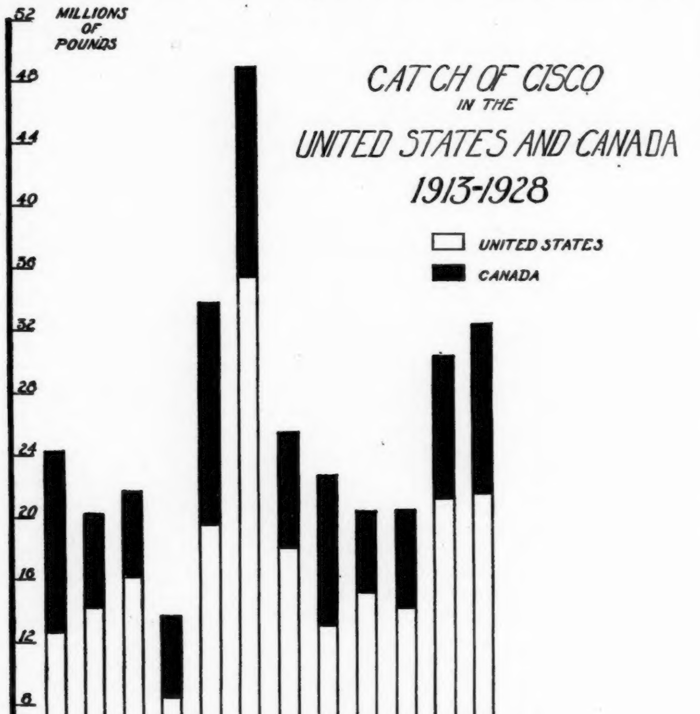
Figure 1 shows the total annual catch of ciscoes, or Lake Erie herring, for the years 1913 to 1928 inclusive, based on statistics collected by the Province of Ontario, the various states bordering Lake Erie, the U. S. Tariff Commission and the United States Bureau of Fisheries. Each column represents the combined catch of Lake



Erie ciscoes of Canada and the United States; the white lower portion of each column represents United States production, the black-colored upper portion represents Canadian production. The ordinates represent millions in pounds, the abscissas represent the calendar years. The figures on which this chart is based are given in Table I.

Table I and figure 1 show that the cisco catch fell from approximately 20 to 24 million pounds during the years 1913 to 1915 inclusive to 13½ million pounds in 1916, then rose to about 33½ million pounds in 1917 and reached the supposedly unprecedented height of nearly 49 million pounds in 1918. The World War no doubt stimulated this production. During the period, 1919 to 1922 inclusive, the cisco production returned to what apparently seems normal, varying from about 20 million pounds in 1921 to about 25¼ million pounds in 1919. In 1923 and 1924 the reported total catch rose to 30,171,402 pounds and 32,200,661 pounds respectively, then dropped to the unprecedented reported figure of about 5½ million pounds in 1925. In 1926 there was a further decrease to 3 million pounds, then a slight increase to about 4½ million pounds in 1927 and finally the virtual extinction, commercially, of the ciscoes in 1928 (1,891,372 pounds), 1929 and 1930. The chart and table show no production values for 1929 and 1930, but from reports in the field we know that the ciscoes have continued to be commercially extinct to the present time, although a slight increase in 1930 has been reported from various ports.

By comparing the white (United States catch) and the black (Canadian catch) portions of each column on the chart, it will be noticed that the fluctuations in the annual catch of Lake Erie ciscoes were not always the same in direction or relative amount in the two countries. Table I shows that previous to 1925 the United States production of Lake Erie ciscoes always exceeded the Canadian, that in the years 1925 to 1927, inclusive, this production was about the same in both countries and that in 1928 the Canadian production equalled more than twice the United States production. But the statistics of both countries agree in showing a big yield in 1923 and in 1924, a *sudden collapse* of the cisco fishery in 1925, and a continuance of this sudden slump through 1928, though I know that later statistics will show that in both countries this slump has persisted to the present time. (See also Table V.) The Lake Erie cisco has not yet recovered its former abundance.

Virtually all are now agreed that the Lake Erie ciscoes are gone although one may still encounter a supreme optimist among the fishermen who believes that the ciscoes are still abundant in the lake, but for one reason or another do not gill in the nets. In 1927, when I first began the investigation of the Lake Erie fisheries, very few fishermen were convinced that the cisco had really disappeared. Even in 1928 and 1929, some fishermen questioned the reality of the collapse and believed that the decrease in abundance was only temporary, that it was only one of the slumps that their experience

taught them recurred periodically in the Lake Erie cisco fishery. (See Table V.) According to the testimony of some of the older fishermen the cisco had disappeared several times before, but had always come back in tremendous numbers for no apparent reason whatsoever. They felt sure history would repeat itself subsequent to 1925, and so, year after year they hoped and waited for the expected return of their cisco. But the cisco did not return. What happened to them? Why did they disappear so suddenly? They could not have been exterminated, so it was argued, for did not the tremendous lifts of the gillnet tugs in 1924 continue to the very last day of fishing in December? Where, then, were these hordes of ciscoes that the fishermen knew were left in the lake in 1924?

The few fishermen's records examined by me and the testimony of many tug captains show that the ciscoes were taken in undiminished numbers to the very end of the fishing season during the "big year", 1924. For instance, the last few lifts of ciscoes recorded by one American tug for the "big cisco years", 1923 and 1924, were as follows:

Date	Boxes of Narrow Gillnets Lifted	Pounds of Ciscoes
December 13, 1923	8	11,620
December 14, 1923	9	12,060
December 15, 1923	8	15,070
December 11, 1924	11	12,515
December 12, 1924	9	5,900
December 13, 1924	12	8,275
December 15, 1924	16	16,955
December 16, 1924	8	7,885

These lifts far exceeded the last lifts taken in previous years in the same amount of gear by the same tug in the same waters. The above lifts averaged 1114.6 pounds per box of nets. The equivalent value in 1921 e.g. was 109 pounds. It has been asserted by some fishermen that the big lifts of the fall of 1924 continued in the spring of 1925, but the records of the tug referred to above do not confirm this statement.

It appears then that the ciscoes were very abundant in 1924 to the last day of fishing in December and were very scarce on resumption of fishing in the spring of 1925. Apparently some catastrophe overtook them during the intervening winter months of 1924–1925. We have no evidence that an epidemic disease wiped them out or that a wholesale migration took place out of Lake Erie or that unfavorable environmental conditions prevailed during several successive spawning or (and) hatching seasons of ciscoes. The abundance of ciscoes in the fall of 1924 apparently argues against their extermination by intense fishing.

And yet, I believe intense fishing by bullnets coupled with an unusual concentration of the ciscoes exterminated them. By degrees I ascertained from various interviews of tug captains that in 1923 and 1924 the ciscoes seemed to have been abnormally distributed in the lake; nearly the entire population seemed to have congregated in these years in the "deep hole" off Long Point, Ontario, and its environs in the eastern end of the lake. Normally, so it was said, ciscoes occurred more or less abundantly over most of the lake in the spring and fall from the Point Pelee area at the west end of the lake to Dunkirk, New York, at the east end with the greatest concentration in the "deep hole" at the eastern end. But during these "big years" (1923 and 1924) ciscoes could not be taken in any quantities west of the "deep hole" area and gillnet tugs from every port on the lake migrated to the Erie (Pennsylvania) district on the American shore and to the Port Dover (Ontario) area on the Canadian shore. Even in the eastern area the ciscoes seemed to have been so restricted during 1923 and 1924 that pound nets set in 35 feet of water off Nanticoke, Ontario, near Port Dover, failed to get them as they did in previous years, but gillnet tugs three miles distant took them in large quantities in 60 feet of water. I am not prepared to state definitely at the present time what factors were involved in this unusual concentration of the ciscoes, but I have some information that indicates that it might have been caused by the unusually large number of severe gales early in 1923. The log of the American gillnet tug previously mentioned records the occurrence of gales in 1923 on March 19, 24, 25, 26, 27, 28, 29, 30, 31, April 1, 2, 8, 11, 13, 14, 15 and 30. It appears highly probable that the unusually prolonged series of gales from March 24 to April 2 inclusive would tend to drive the cisco population out of the shallow water overlying the so-called "plain area" into the "deep hole" area in the eastern sector of the lake. Whatever the cause may have been, the consensus of opinions among the fishermen is that concentration actually took place.

Government statistics on the catch should furnish us some information on the accuracy of these reports. Table II shows the percentage of the annual American catch of Lake Erie ciscoes taken out of ports located in the States of New York and Pennsylvania in various years during the period 1885–1928. The statistics employed for this table were obtained from various state and federal governmental publications. The percentages show that previous to 1903 the New York and Pennsylvania fishermen usually produced less than half of the annual American catch of the Lake Erie cisco, that during the period, 1903–1921, these fishermen usually took from 50%–75% of the total yearly catch, and that subsequent to 1921 they produced more that 90% of the cisco catch. The figures of Table II seem to indicate that the unusual congregation of the ciscoes in the eastern area of the lake occurred not only in 1923 and 1924, as stated by the fishermen, but also in 1922.

If reference is made to Table III which shows the United States catch of ciscoes by states for 1885–1928, it will be noticed that a sharp decline in the annual yield took place in 1922, 1923 and 1924 in the state of Ohio (Michigan produces virtually no ciscoes), but not in New York and Pennsylvania. If the decrease in the Ohio catch was due to the migration of the ciscoes to the eastern area it might be expected that Ohio's loss would be Pennsylvania's and New York's gain. The data of Table III show that Ohio's catch decreased 3,254,498 pounds in 1922, while the combined catch of New York and Pennsylvania increased 2,310,652 pounds. Compensation was not complete since Ohio's loss exceeded the more eastern states' gain by 943,846 pounds. However, this excess would in all probability disappear if the gain in the catch of the Canadian tugs at Port Dover, Ontario, could also have been considered.

In spite of the fact that the figures of Tables II and III suggest a migration of the ciscoes in 1922 to the eastern sector of Lake Erie, it is still possible to believe that the increase in the annual catch in Pennsylvania and New York waters in 1922–1924 was due entirely to the migration of the Ohio tugs to these waters and not to the congregation of the ciscoes there. In other words, to believe that the ciscoes were depleted in Ohio and that the big yield of the eastern states was due entirely to increased fishing intensity. In order to prove concentration, we must then have in addition to data on total yield and the percentage of this yield taken in each state some evidence to show that the catch of ciscoes per unit or area of gear increased during the period 1922–1924 over preceding years.

Fortunately we were able to find one tug captain who had kept a rather complete log of his fishing operations from 1918 to 1928. The data on the catch per unit of gear taken from this log are shown in Table IV. It shows for each year the dates of the fishing season covered by the data, the ports out of which the tug operated, the total number of bullnet gangs lifted for ciscoes, and the average number of pounds of ciscoes taken per gang of bullnets.

The data on the average number of pounds of ciscoes per gang of bullnets show that a concentration of the ciscoes actually occurred in 1923 and 1924 since the catch per gang increased sharply in these years and was greatest in these years. These data suggest further that no marked congregation of ciscoes took place at Erie, Pennsylvania, in 1922, as was indicated by the data of Tables II and III, since the tug did not find it necessary to migrate to Erie, Pennsylvania, as in other years to secure its quota of ciscoes, and the catch per gang for 1922 at Ashtabula, Ohio, compared favorably with that for 1921 at Erie, Pennsylvania.

The absence of a marked concentration of ciscoes in the eastern area in 1922 is further indicated by the fact that the ciscoes were more abundant at Rondeau, Ontario (opposite Cleveland, Ohio), in 1922 than in 1921, 1923 and 1924. Table V shows the average catch

of ciscoes per pound net at Rondeau, Ontario. It seems then that the increase in the cisco catch in New York and Pennsylvania in 1922 must be accounted for, at least in part, by an increase in fishing intensity. That the average yield per net was much less in 1922 than in any year preceding 1921 may suggest a partial concentration of the cisco population in 1922. The small catch per net at Rondeau in 1923 and 1924 coupled with the fact that the gillnet lifts of ciscoes in these years were unusually large at Erie, Pennsylvania and Port Dover, Ontario, is additional evidence of the eastern concentration of these fish.

Although our statistical data seem somewhat conflicting in regard to the migratory movements of the ciscoes in 1922, they substantiate the fishermen's statements that a marked concentration of ciscoes took place in the "deep hole" area in the eastern end of Lake Erie in 1923 and 1924.

It appears safe to assume now that the unusual abundance of ciscoes in 1923 and 1924 in the eastern sector of Lake Erie was due to the unusual congregation of the species in this area and not to an actual abundance of individuals in the lake; the apparent abundance of ciscoes was not real; the ciscoes were normal in numbers in the lake in 1923 and 1924 in spite of the tremendous lifts made by the gillnet fishermen.

On this basis we are now able to suggest a plausible explanation for the *sudden* collapse of the cisco fishery in 1925. Computations based on the data of Table I show that in 1923 and 1924 the fishermen took a total of some 20½ million pounds of ciscoes in excess of the average yield of a normal year or an excess yield equal to the production of a normal year. If the population in the lake was only normal in abundance in 1923 and 1924, as all evidence indicates it was, and if we assume that the concentrated ciscoes of the fall of 1924 resumed their normal distribution in 1925, then it is not difficult to see why the cisco fishery collapsed suddenly in 1925. The total excess yield of some 20½ million pounds in 1923 and 1924 simply reduced the stock of marketable fish in the lake to such a point that under normal distribution the number of ciscoes per unit area was so small that the fishery collapsed. The catch per gang of bullnets as recorded in Table IV fell from 321.9 pounds in 1924 to 35.1 pounds in 1925.

The fishermen interviewed believe that this assumed return to normal distribution actually took place, since lifts of ciscoes, all of which were small, were again taken out of the several herring ports in 1925 and varied in size with the several ports in more or less the same manner as the larger lifts did previous to 1923. I have no data bearing directly on this question of return to a more or less normal distribution, except the data on the average catch per gang (Table IV) which show the extreme paucity of ciscoes per unit area in Pennsylvania in the years 1925 to 1928 inclusive. But some return to normal distribution must have taken place, otherwise the unusually large lifts

of 1924 would have continued in 1925. If some catastrophe had overtaken the ciscoes during January or February, 1925, the fishermen would have seen some evidence of it on resumption of fishing in March. Their bottom nets would in all probability have picked up the skeletons or decomposed bodies of the dead fish. The fact that the percentage of decrease (92%) in the catch of ciscoes in Pennsylvania in 1925 (see Table III) was much greater than in either New York (78%) or Ohio (70%) may be indirect evidence that part of the cisco population had migrated out of Pennsylvania waters in 1925. The year 1925 is the only one on record in which the catch of ciscoes in New York exceeded that in Pennsylvania. Ignoring all other considerations, if no migration occurred it might reasonably be expected that the percentage of decrease in the Pennsylvania catch in 1925 would approximate that of the New York and of the Ohio catch.

In addition to the excessive fishing and the return towards normal distribution, another factor must have been involved in the collapse. The excessive fishing seriously depleted the numbers of sexually matured ciscoes before spawning time in the fall of the year thus leaving relatively few breeders in the lake to spawn in 1923 and 1924. The progeny of the decimated breeders was so reduced in numbers below the normal, that its appearance in the commercial catch of 1925 and later years failed to bring production back to normal. Our age determinations show that the gillnet lifts of ciscoes are composed almost entirely of individuals in their second and third year of life, these age groups comprising 82.8% of the lifts taken in 1927 and 1928 at Sandusky, Vermilion and Lorain, Ohio, and 97.8% of the lifts taken in 1928 at Erie, Pennsylvania. Other factors may have been involved in the disappearance of the ciscoes, but the three discussed above (unusual concentration, intensive fishing and depletion of the breeders) adequately explain the sudden collapse of the fishery in 1925.

It might be asked here whether the factors operative in the distribution of the Erie ciscoes in 1923 and 1924 might not have been present during the big years, 1917 and 1918. In other words, might not the situation with respect to the ciscoes in 1923 and 1924 have been much the same as it was in 1917 and 1918 but with entirely different consequences, and the factors discussed above were after all not the controlling factors in the disappearance of the cisco in 1925? From the evidence in hand it appears that the heavy production of ciscoes in 1917 and 1918 although stimulated by the war was due in part to the actual abundance of the fish in the lake and not to an unusually marked concentration of ciscoes in a small circumscribed area in the lake. Tug captains have informed me that, though the annual yields in 1917 and 1918 were large, the individual gillnet lifts of these years were much smaller, on the average, than those of 1923

TABLE I

LAKE ERIE CISCOES

ANNUAL CATCH IN POUNDS, 1913–1928

Year	United States	Canada	Grand Total
1913	12,513,180	11,608,428	24,121,608
1914	14,107,982	5,981,542	20,089,524
1915	15,978,219	5,573,688	21,551,907
1916	8,336,954	5,210,531	13,547,485
1917	19,453,146	14,157,839	33,610,985
1918	35,290,527	13,531,993	48,822,520
1919	17,846,290	7,425,713	25,272,003
1920	12,893,192	9,651,284	22,544,476
1921	14,964,135	5,225,300	20,189,435
1922	14,021,882	6,306,318	20,328,200
1923	20,930,284	9,241,118	30,171,402
1924	21,292,733	10,907,928	32,200,661
1925	2,817,000	2,840,000	5,657,000
1926	1,449,000	1,573,000	3,022,000
1927	2,350,000	2,309,000	4,659,000
1928	618,024	1,273,348	1,891,372

and 1924, i.e. the ciscoes were less concentrated in 1917–1918 than in 1923–1924, and the ciscoes were more or less abundant everywhere in the lake in 1917 and 1918.

Records of the American tug previously referred to show that lifts of ciscoes made during the period July 20–September 17, 1918, out of Ashtabula, Ohio, averaged 1,446 pounds per lift. During approximately the same period (July 24–October 2) and with approximately the same fishing intensity, this same tug took in 1924 out of Erie, Pennsylvania, an average of 3,843 pounds of ciscoes per lift. Tables II, III and V give additional evidence that points to the absence of a marked concentration of the ciscoes in the eastern sector in 1917 and 1918. The data of Table II show that in 1917 only 31.3% of the American catch was taken out of New York and Pennsylvania ports, while in 1918 some 74.8% was taken out of these ports in contrast to 96.2% and 99.2% taken in 1923 and 1924 respectively. Table V shows that in contrast to the "big years", 1923 and 1924, the ciscoes were very abundant at Rondeau, Ontario, up the lake opposite Cleveland, Ohio, in 1917 and 1918, when the catch of ciscoes per pound net averaged 41,611 pounds and 21,656 pounds respectively. The actual figures of the annual catch are shown in Table III. These show not only that some 69% of the United States catch in 1917 was taken from Ohio waters, but that the 13,365,657 pounds taken was the largest annual catch on record for Ohio in recent years. The annual

report of the Pennsylvania Department of Fisheries for 1917 also states that there was a heavy run of herring in the upper lake ports and that only a few Ohio tugs operated out of Erie in 1917. In this year production in Pennsylvania was normal, while that in New York was abnormally low. In 1918, production returned to normal in New York, but was by far the highest ever recorded for Pennsylvania and was the second highest in Ohio in recent years. It is clear from the annual catch of the next three succeeding years that in spite of the heavy production in 1917 and 1918, the ciscoes were not depleted. Production may have been stimulated by the war, but the ciscoes must also have been abundant in the lake.

The data I have indicate, then, that the situation with respect to the ciscoes was not the same in 1923–1924 and in 1917–1918. The heavy production of the latter years was not due to the unusual concentration of the ciscoes in a restricted area as it was in the former years.

TABLE II

PERCENTAGE OF THE ANNUAL AMERICAN CATCH OF LAKE ERIE CISCOES TAKEN IN THE STATES OF NEW YORK AND PENNSYLVANIA IN VARIOUS YEARS DURING THE PERIOD 1885–1928

Year	New York	Pennsylvania	New York and Pennsylvania
1885	0.4	17.6	18.0
1890	4.6	20.6	25.3
1893	—	—	38.6
1897	4.6	35.3	39.9
1899	9.9	32.1	42.1
1903	17.1	65.4	82.6
1908	19.0	35.8	54.8
1913	23.8	61.3	85.1
1914	26.9	38.8	65.7
1915	29.3	51.1	80.4
1916	33.8	39.0	72.8
1917	4.4	26.8	31.3
1918	9.4	65.4	74.8
1919	22.0	33.1	55.1
1920	18.9	49.3	68.2
1921	15.6	57.3	72.9
1922	27.1	67.2	94.3
1923	27.6	68.6	96.2
1924	35.8	63.4	99.2
1925	60.0	37.7	97.7
1926	14.9	77.7	92.6
1927	26.0	69.1	95.2
1928	38.6	57.6	96.2

To summarize, it may be stated, then, that the disappearance of the Lake Erie ciscoes in 1925 is explained on the basis of a series of unusual circumstances. The ciscoes congregated in a relatively small circumscribed area of the lake in 1923 and 1924; the gillnet fishermen followed them and in the firm belief that the supply was extremely abundant they fished excessively for the ciscoes, in many cases slaughtering them indiscriminately by the tons; tons of ciscoes taken in the bullnets failed to reach the market. The apparent abundance of the ciscoes in 1923–1924 was not real but due to their abnormal distribution; on resumption of normal distribution in 1925 the fishery collapsed for the ranks of the adults had been decimated, the breeders had been reduced in numbers, and the progeny, likewise reduced in numbers below the normal, was unable to bring production back to normal. The cisco was commercially exterminated by overfishing.

TABLE III

UNITED STATES CATCH IN POUNDS OF LAKE ERIE CISCOES, 1913–1928*

Year	New York	Pennsylvania	Ohio and Michigan	Total
1885	83,200	3,397,000	15,874,700	19,354,900
1890	1,807,120	8,012,510	29,048,653	38,868,283
1893	—	—	12,842,180	20,931,076
1897	898,010	6,940,932	11,799,347	19,638,289
1899	3,321,558	10,742,315	19,363,924	33,427,797
1903	1,505,324	5,750,352	1,532,949	8,788,625
1908	2,009,000	3,796,000	4,794,100	10,599,100
1913	2,914,824	7,669,755	1,928,601	12,513,180
1914	3,800,088	5,468,819	4,839,075	14,107,982
1915	4,685,352	8,161,811	3,131,056	15,978,219
1916	2,816,845	3,254,371	2,265,738	8,336,954
1917	865,132	5,221,612	13,366,402	19,453,146
1918	3,313,442	23,095,279	8,881,806	35,290,527
1919	3,933,120	5,899,890	8,013,280	17,846,290
1920	2,438,146	6,361,253	4,093,793	12,893,192
1921	2,339,087	8,569,964	4,055,084	14,964,135
1922	3,803,112	9,416,591	802,179	14,021,882
1923	5,781,138	14,349,200	799,946	20,930,284
1924	7,625,964	13,449,438	217,331	21,292,733
1925	1,689,913	1,060,953	66,134	2,817,000
1926	215,717	1,126,321	106,962	1,449,000
1927	612,050	1,624,737	113,213	2,350,000
1928	238,446	356,070	23,508	618,024

*The data for 1913–1924 were furnished by the U. S. Tariff Commission, those for other years were secured from government publications.

TABLE IV

AVERAGE NUMBER OF POUNDS OF CISCOES TAKEN EACH YEAR PER GANG OF BULLNETS BY ONE AMERICAN GILLNET TUG DURING THE PERIOD 1920–1928*

Fishing Season	Port	Number of Bullnet Gangs Fished	Average Number of Pounds of Ciscoes per Gang
July 24–Dec. 12, 1920	Ashtabula, O.	775	139.2
July 20–Oct. 26, 1921	Erie, Pa.	810	287.6
July 20–Dec. 1, 1922	Ashtabula, O.	930	268.9
June 20–Nov. 25, 1923	Erie, Pa.	908	422.8
June 4–Oct. 17, 1924	Erie, Pa.	946	321.9
Aug. 14–Oct. 22, 1925	Erie, Pa.	68	35.1
July 9–13, 1926	Erie, Pa.	62	43.5
July 14–Nov. 27, 1927	Erie, Pa.	727	44.2
June 19–Aug. 28, 1928	Erie, Pa.	744	27.0

*I am greatly indebted to Captain Charles R. Hoskins, Erie, Pennsylvania, for the use of his log in the compilation of these data and in the procurement of other valuable information on the cisco fishery.

TABLE V

AVERAGE NUMBER OF POUNDS OF CISCOES PER POUND NET TAKEN AT RONDEAU, ONTARIO, IN VARIOUS YEARS DURING THE PERIOD 1899–1927*

Year	Average Number of Lbs. per Net	Year	Average Number of Lbs. per Net
1899	99,020	1914	7,107
1900	56,667	1915	2,889
1901	50,267	1916	6,924
1902	7,208	1917	41,611
1903	8,188	1918	21,656
1904	6,440	1919	5,117
1905	3,097	1920	5,820
1906	8,883	1921	753
1907	9,130	1922	2,196
1908	17,300	1923	337
1909	13,366	1924	285
1910	22,316	1925	81
1911	48,005	1926	225
1912	55,546	1927	104
1913	30,011		

*I am greatly indebted to W. D. Bates who furnished me the statistics employed for this table.

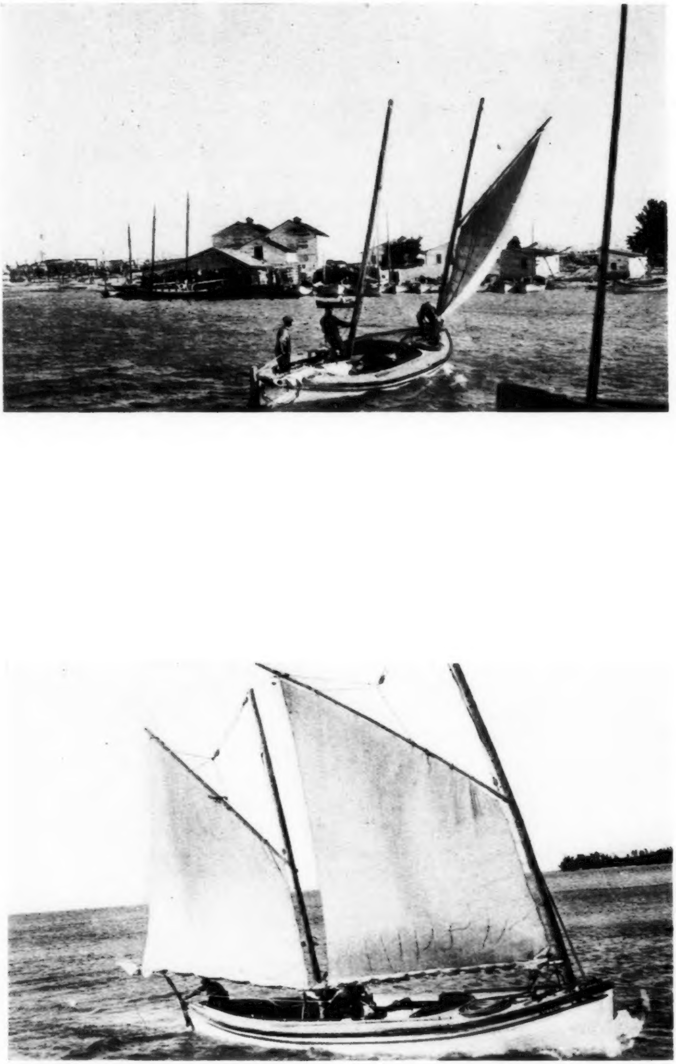


FIG. 1. Fishing station at George Id., Lake Winnipeg.
(By courtesy of Mr. N. A. Beketov.)

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FISHING INDUSTRY AND FISHERIES INVESTIGATIONS IN THE PRAIRIE PROVINCES

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INTRODUCTION

Except in certain of the most westerly districts, all the lakes and rivers in Manitoba, Saskatchewan and Alberta belong to the Hudson's Bay Drainage System. This drainage system accounts for over one million square miles, including a large part of the Northwest Territories east of Great Slave Lake and parts of North Dakota, Minnesota, Ontario and the greater part of Quebec in addition to the three above-mentioned provinces. We can classify the lakes for convenience into the four following categories, namely:

1. *Large Lakes*, including Lakes Winnipeg, Winnipegosis, Manitoba and certain adjacent waters as Dauphin, Waterhen, etc., most of them formerly included in the glacial Lake Agassiz, which had a total area of about 110,000 square miles and occupied parts of Manitoba, Saskatchewan, and Ontario in Canada and parts of North Dakota and Minnesota in the United States. Lake Agassiz formerly drained southeastwards through the so-called Warren River into the Mississippi River System.

During that time many southern fish: *Ictiobus bubalis*, *Carpiodes velifer*, several species of *Moxostoma*, *Ameiures*, many species of *Cyprinidae*, etc.,—penetrated into the Hudson Bay drainage. Later on a channel was opened toward the northeast through the Nelson River into the Hudson Bay, leaving as successors of Lake Agassiz several other lakes, with a mixed Ichthyofauna.

All these lakes which now drain into the Nelson River are not strongly alkaline. Water analyses show that the percentages of total solids are not very high. The maximum, found in Lake Winnipegosis, was 1265 parts per million. The average salinity for the whole of Lake Winnipeg is approximately 220 parts per million. (A. Bajkov. 1.) As might be expected, all these lakes are comparatively shallow, the maximum depth of Lake Winnipeg being 20 metres, of Lake Winnipegosis 18 metres, of Lake Manitoba only 7 metres. The bottom of each of these lakes is composed of dark grey mud, the particles of which measure 0.001-0.005 mm. together with a considerable amount of organic matter from dead plankton. Small areas of sand, clay, humus and gravel also occur.

The areas of the three largest lakes are as follows: Lake Winnipeg —9,460 square miles, Lake Winnipegosis—2,086 square miles, Lake Manitoba—1,775 square miles. The areas of four less important lakes are: Moose Lake—552, Cedar Lake—285, Lake Dauphin—196 and Lake St. Martin—125 square miles.

2. *Alkaline Lakes.* These lakes are situated chiefly in Western Manitoba, Saskatchewan and Southern Alberta in Canada and in North Dakota in the United States. Most of them represent portions of the former Lake Souris. They are strongly alkaline and some of them contain 10–17,000 parts per million of dissolved solids. None of them possess outlets and most of them are very shallow and comparatively small. They are of little commercial importance at the present time but are very interesting from the standpoint of fish-culture, as it has been found that whitefish and cisco can live and breed in such alkaline water. They are very rich in fish foods and consequently the above-mentioned fishes grow about twice as fast as in the lakes of the previous category, and the quality of meat is very high.

The species of native fishes in certain of these lakes are common sucker (*Catostomus commersonhii*), Pike (*Esox lucius*), Perch (*Perca flavescens*), Nine-spined Stickleback (*Pygosteus pungitius*), Brook Stickleback (*Eucalia inconstans*), several species of *Notropis* and other minnows.

3. *Northern and Eastern Lakes.* Numerous lakes of different size come under this category. In general they lie in well forested areas and differ from the previous groups in their clearer, non-alkaline water. They tend somewhat towards the alpine type and their fish fauna contains more northward-ranging species. To this category belong Lake Athabasca and Reindeer Lake with an area of more than 2,000 square miles each, Southern Indian Lake—1,500 square miles, Wallstone and Etawney Lakes, with an area more than 600 square miles each, Island Lake with an area of 550 square miles, Granville Lake with an area about 400 square miles and numerous others large and small. Most of them are unexploited or exploited very little at the present time.

4. *Alpine Lakes.* These are all situated in the Rocky Mountains of Western Alberta. Some belong to the Hudson's Bay drainage system, others to the Arctic through the Mackenzie River. They are entirely different from any of the preceding, being deep, cold and often very clear. They have no commercial value but are of great interest to the sportsman and scientist. The fish fauna contains certain arctic and alpine species, such as Dolly Varden Trout (*Salvelinus alpinus malma*), Rainbow Trout (*Salmo irideus*), Arctic Grayling (*Thymallus signifer*), Rocky Mountain Whitefish (*Coregonus williamsoni*), etc. Some of them are admirably adapted for stocking with Speckled Trout. (A. Bajkov 2 and 3.)

History and Organization

At the present time the fishing industry in the Prairie Provinces ranks among the most extensive fresh-water fisheries in the world. Fishing has been carried on by white settlers in the Prairie region for more than a hundred years but has only attained commercial im-

Fig. 2. Typical fishing tugs on Lake Winnipeg.

Fig. 4. Whitefish eggs from the stomach of whitefish, Lake Winnipegosis.

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portance during the latter half of this period. The earliest available statistics as to the value of the yearly catch are for 1886, about $150,000. Since that time the value has risen to about $4,000,000 at the present time. The total capital investment of the fisheries was in 1886 only about $200,000 but at the present time it has risen to about one and a half million dollars. The number of persons employed in the fishing industry has increased from one and a half thousand to more than six thousand during this period.

Nevertheless, the fishing industry is only in its infancy. There are many great lakes which are now unexploited as well as the coast line of Hudson's Bay proper, which in future might be more important from the standpoint of the fish industry than the inland lakes.

At the present time the most important fisheries are those of Manitoba, chiefly on account of its three great lakes which are fished by large outfits. These outfits usually consist of a fleet of fishing boats each about 40 feet in length and equipped with gasoline engine, and one or two steam boats for transportation of the fish to points on the railways. The sailboats which were formerly used for fishing have been almost entirely converted during the last period into power boats. (Fig. 1) and (Fig. 2).

Only gill nets of different mesh are used at the present time and fishing is carried on both in summer and winter.

Nearly all of the fish are placed on the Canadian and American markets in a fresh or frozen condition, except goldeyes and partly tullibees, most of which are smoked. A few years ago a small amount of white fish was also smoked for the local markets.

Ichthyofauna

The freshwater fishes of this area comprise about one hundred known species and subspecies, belonging to nineteen families as follows: *Petromyzonidae*, *Acipenseridae*, *Amiidae*, *Siluridae*, *Catostomidae*, *Cyprinidae*, *Hiodontidae*, *Coregonidae*, *Thymallidae*, *Salmonidae*, *Esocidae*, *Gasterosteidae*, *Percopsidae*, *Centrarchidae*, *Serranidae*, *Percidae*, *Sciaenidae*, *Cottidae* and *Gaddidae*. (A. Bajkov 4.)

The dominant families in points of number of species are the *Cyprinidae*, *Catostomidae*, *Percidae* and *Coregonidae* but only the two latter are of much commercial importance. The following review is intended to give some idea of the status and biology of the more valuable species.

Whitefish (*Coregonus clupeaformis*, Mitch.)

This is one of the most important fishes of the region, the annual catch averaging around 4,000,000 lbs., for each of the Prairie Provinces. At the present time the average weight of whitefish in the catches is three pounds. The largest fish examined by the writer was one of 16 lbs., from Lake Winnipeg. This fish was over twenty

years old. Twenty or even fifteen years ago specimens weighing twenty and twenty-five pounds were not rare. We have no data concerning the average weight of whitefish twenty years ago, but undoubtedly it was somewhat more than now. Usually the development of the industry is accompanied by a decrease in the average weight of catches, but it would be wrong to connect a decrease of average weight with decreasing number of fish. Together with a development of industry and of fish culture we can observe a decrease of average weight in connection with a more rapid destruction and replacement which makes the average life of the fish very much shorter. As shown by examination of their scales, whitefish reach commercial size when five or six years old. The main bulk of the catches consists of fish between five and ten years old. Very few fish reach a greater age than fifteen years. The following table shows the average growth of whitefish for Lakes Winnipegosis and Winnipeg. (The number of fish examined was over seven hundred.)

Lake Winnipegosis			*Lake Winnipeg*		
Age in Years	Average Length in mm.	Average Weight in Lbs.	Age in Years	Average Length in mm.	Average Weight in Lbs.
1	175		1	120	0.05
2	175	0.15	2	170	0.14
3	350	1.4	3	325	1.3
4	390	1.8	4	380	1.7
5	420	2.3	5	420	2.3
6	450	2.5	6	450	2.5
7	480	3.00	7	480	3.00
8	500	3.3	8	500	3.3
9	520	3.7	9	520	3.7
10	540	4.2	10	540	4.2
11	560	4.8	11	560	4.8
12	575	5.5	12	575	5.3
13	585	5.8	13	585	5.8
14	592	6.5	14	590	6.5
15	600	7.00	15	600	7.00
16	610	7.6	16	615	8.00
17	620	8.00	17	630	10.00

A quite similar growth rate is found in other lakes of the region, but in certain alkaline lakes, where whitefish have been introduced artificially, the rate of growth is much higher. For instance, in Quill Lakes, Sask., a specimen four years old weighed four and a half pounds.

The rates of growth of males and females are about the same.

As shown by examination of their stomach contents (A. Bajkov 5) the young whitefish during the first summer feed mostly on plankton, but from their second year onwards they live mainly on organisms

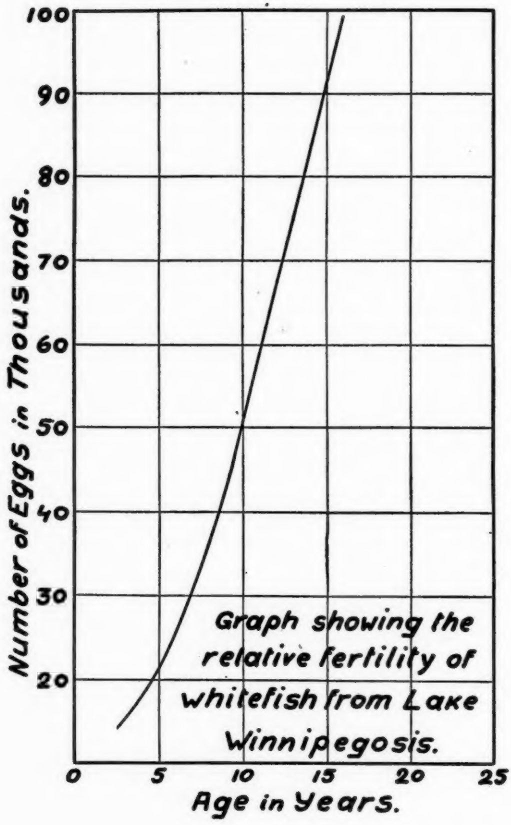
from the bottom. This food varies at different seasons and in different lakes. In Lake Winnipeg the most important food items are small amphipods (chiefly *Pontoporeia hoyi*) and the larvae of insects (chiefly "Fish-fly" *Hexagenia limbata* and *Hexagenia rigida*, also *Trichoptera* and *Chironomidae*). In Lakes Winnipegosis and Manitoba the fish feed mostly on mollusks (*Valvata tricarinata*, *Valvata sp.*, *Amnicola sp.*, *Pisidium spp.*, etc.) although during the end of Winter at certain localities stomachs of whitefish are full of green Chironomid larvae. The fish from the former lake are better flavored.

During the period of whitefish investigation several hundreds of whitefish stomachs were examined in connection with the estimation of the daily consumption of food by whitefish in the Prairie Lakes and it was found that the average consumption of food daily is as follows: Amphipods and other small crustacean—63.4, small mollusks—144.5; insect larvae—100.0. Total rough weight in grammes—8.7 (A. Bajkov 5). This will be 3.28 kg., rough weight per year, which accords quite well with the average increase in weight of whitefish of 200 grammes per year. This quantity of 3.28 kg. was counted as a minimum, without including all the other items of food, such as aquatic earthworms, leeches, water-mites and other food of secondary importance, which cannot be estimated exactly.

The spawning period of whitefish in the Prairie Provinces occurs usually in October and November. For this purpose the adult whitefish gather into large shoals, leaving the deepest parts of the lakes and coming towards shore to shallow places or entering rivers. After spawning, the whitefish return at once to the deep waters. The spawning places are more or less constant. The spawning process takes place at night and begins shortly after sunset. They first rise to the surface and make heavy splashes, like a flock of wild ducks. The author has observed such splashes on Lake Winnipegosis. This "Play", quick motions and rising to the surface are an effect of sexual excitement. Whitefish lay their eggs in small batches over a period of several days. This habit would give the spawn a much better chance of survival than if all the eggs were laid together. As shown by examination of the stomachs of fishes which eat whitefish eggs, as well as by examination of naturally laid eggs, it was a wrong opinion that only a few eggs of the whitefish are fertilized under natural conditions. It was found by the writer that the percentage of fertilized eggs under favourable spawning conditions may fluctuate very considerably and may reach 85%. It was found also that the average life of fully ripe sperm is in water 16 minutes (maximum 30 minutes), while in air only 6 minutes, i.e. less than half as long.

All the evidence indicates that whitefish spawn every year after reaching four years, as no large fish with immature gonads have been found during the spawning season.

Various authors estimate the average fertility of whitefish as 35,000 eggs. This is more or less accurate. From the results of counting



ovarian eggs in various sizes of ripe females from Lake Winnipegosis (see Graph, which has been constructed to show the number of eggs in relation to age of the fish), during increase in weight of the fish from three pounds to six pounds, the number of eggs increases approximately 14,000 per pound.

Downing in 1910 (7) says that the greatest number of whitefish eggs observed was 150,000 from an 11 pound fish, but we believe that the maximum is higher because whitefish sometimes reach a considerably greater weight, we ourselves having examined one weighing sixteen

pounds. Taking the average duration of the life of the whitefish in the Prairie Lakes as ten years, we have calculated, on the basis of the number of eggs found in fish of different ages that it can lay about 250,000 eggs.

A great number of whitefish eggs are destroyed by whitefish themselves (see Fig. 4). Eggs are also eaten by perch and tullibee. The percentage of mortality of fertilized eggs and fry, under natural conditions, is very great, perhaps somewhere about 99%.

Under natural conditions, in a mean water temperature of 17° C. (35°F.) eye spots appear on the fertilized eggs, after about one and a half months, and the full incubation period is about 140 days.

Very little, if anything, is known about the biology of whitefish fry. Only a few investigators have found whitefish fry under natural conditions. As far as I know, only Professor W. J. K. Harkness of Toronto has found whitefish fry in numbers in Lake Ontario by means of small mesh seines. In the first week of July (1930) in the northern portion of Lake Winnipeg, on calm days many schools of whitefish fry appeared, which were swimming near the surface, about one foot deep, and were hunting for planktonic copepods (mostly *Diaptomus*). This was in the open lake a few miles from the spawning ground. The number of fry in the schools were from 7–100 and probably more. The size varied from 20 to 25 mm., and even during this period they can be easily identified by the number of gill rakers and by the maxillary. Several hundred of them were caught by means of a hand insect-net and preserved.

Whitefish in the Prairie Provinces are protected by limitation of catches, regulation of the mesh of the nets used and by a closed season during the spawning period and are also extensively propagated artificially. There are three large hatcheries, capable of dealing with approximately 200 million whitefish fry, but it is not every year that the hatchery officers can collect such an amount of eggs. Two of these hatcheries are situated in Manitoba, at Lakes Winnipeg and Winnipegosis and one at Fort Qu'Appelle, Sask. At the present time the Prairie Lakes are an important region for the propagation of whitefish. This species keeps principally to the northern, deeper portions of Lakes Winnipeg and Winnipegosis. The whitefish industry is now in a healthy condition and during the last few years the fish show an increase in number.

The Various Forms of Tullibee

There are several species of *Leucichthys* in Lakes Winnipeg, Manitoba and Winnipegosis, known under the common name of "Tullibee." Fishermen recognize six different kinds of this fish: Tullibee, Black-backed Tullibee, Light-backed Tullibee, Green-backed Tullibee, Silver-backed and Red-fin Tullibee. The latter is probably a cross between whitefish and tullibee. There are also several intermediate

forms, which are probably also crosses between some of the above mentioned fish.

The commonest species are "Black-backed" and "Light-backed" which can be very easily distinguished from each other. Therefore, the industry recognizes these two distinct species of Tullibee.

Neither of these is a homogeneous group but consists of several species. The dominant species for "Black-backed" is:

1. *Leucichthys Tullibee* (Richardson)—Tullibee with gill rakers (43–53).

The dominant species for "Light-backed" is:

2. *Leucichthys Zenithicus* (Jordan and Evermann) Longjaw with gill rakers (35–41).

There is some admixture in both of these categories, of a species intermediate in color, i.e.

3. *Leucichthys Nipigon* (Koelz)—Tullibee, which is very easily separated by the larger number of gill rakers (55–59), whereas all the others have fewer than 54 gill rakers.

Among the "Black-backed" fish, there is also an admixture of other species, such as *Leucichthys nigripinnis* (Gill) and probably *Leucichthys artedi* in Lake Winnipeg from the East.

Besides these, there is in Lake Winnipeg one very common species, probably *Leucichthys hoyi*, which reaches only 6–6½ inches in length and has no economic importance. A large number of this fish was collected by means of small mesh nets in shallow water near Gimli (Lake Winnipeg). All these fish had ripe sexual products. Several other species occur in the northern lakes and rivers and Tullibee investigations are in progress now. Usually, however, one or two species constitute the bulk of any large catch.

In this report we shall speak only about the two most important species, namely: "Black-backed" Tullibee, meaning *Leucichthys tullibee* and "Light-backed" Tullibee, meaning *Leucichthys zenithicus*.

Rates of Growth of the Black- and Light-Backed Tullibee

The rates of growth of these two species are not the same. The Black-backed tullibee grows very much faster than the Light-backed.

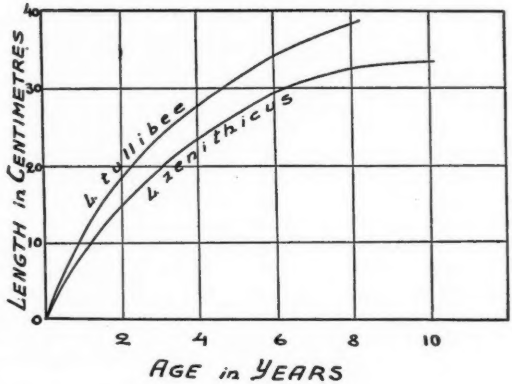
About one hundred fish were examined (fifty of each species) and the results are shown in the following graph illustrating the rate of growth of Lake Winnipeg Tullibee.

The food of the different species is not the same. *Leucichthys zenithicus* feeds mostly on amphipods (*Pontoporeia hoyi*) and larvae of aquatic insects (*Chironomus*, *Hexagenia*, etc.).

The food of *Leucichthys tullibee* consists of about the same items as the previous species.

Leucichthys nigripinnis is a plankton feeder, it prefers chiefly copepods (*Cyclops* and *Diaptomus*).

Leucichthys nipigon is also a plankton feeder. In the stomachs of



this species were found together with *Diaptomus*, *Cyclops*, also *Daphnia longispina*, *Leptodora kindtii* and *Mysis relicta*.

The small species of Tullibee is entirely a plankton feeder, the main item of its food being *Diaptomus*.

All the known species of Tullibee in the Prairie Provinces spawn in the fall. Neither of the two important species spawns before four years old, but in the third year the ovaries can be microscopically distinguished from the testes. Both species spawn every year after reaching four years. The average fertility of both of these Tullibee is 15–20,000 eggs.

At the time of first spawning Black-backed Tullibee reach about 300 mm. (12″) in length, but the Light-backed only 250 mm. (about 10″).

Although both of these tullibees are widely distributed throughout Lakes Winnipeg, Winnipegosis and other lakes, they have different habitats. The light-backed prefers shallow waters near the shore or bays. Along the shore of Lake Winnipeg there are several bays with a depth of about 2–5 fathoms where the Light-backed Tullibee represent about 75% of the whole catch.

Along the eastern shore of Lake Winnipeg there is deeper water and in some places, quite a considerable current. Here Black-backed Tullibee are mostly found. Generally speaking the first species is more abundant in Lake Winnipeg than the second one.

The Tullibee fishing is one of the most important operations during the Fall and Winter. The annual catches for Manitoba average about 10,000,000 lbs. (about 7,000,000 lbs. of which are obtained from Lake Winnipeg alone), for Alberta about 260,000 lbs. and for Saskatchewan over 100,000 lbs. The tullibees are protected by limitation of the catches, but are not propagated artificially.

Goldeye (Hyodon Chrysopsis Richardson)

(=*Hiodon alosoides—Rafinesque*)

This fish is of considerable economic importance in the Province of Manitoba, where the annual catch averages about one million pounds. Practically half of this amount is caught in Lake Winnipeg during the winter period. In Saskatchewan and Alberta the goldeye is not of much economic importance, the total catch per year being only about 6,500 lbs. in the former, this amount being obtained entirely from the Saskatchewan River.

In Manitoba this species is widely distributed in the southern and middle narrow portion of Lake Winnipeg, where it is extremely abundant in shallow bays. It is very scarce in Lake Manitoba where only a few individuals are caught during the fishing season. It is again very common in Lake Winnipegosis and Lake Dauphin. The best fish is that from Lake Winnipeg. Lake Winnipegosis and Lake Dauphin goldeye are not so fat nor so delicious in flavour as in the former lake. This depends somewhat on food.

The food of goldeye is quite variable. It is impossible to give the exact percentage of different food items of goldeye because it depends on seasons and localities.

Generally speaking goldeye is a surface feeder. The fact that in the stomachs of goldeye caught during the night period near the surface, above the depth of several fathoms, often are found great amounts of deep water organisms such as *Daphnia longispina*, which come to the surface at night, shows that the goldeye is mostly a night feeder.

They feed mostly on different terrestrial and aquatic insects, and their larvae. In several localities, especially in the streams, it is a very game and vigorous fish on the hook and takes a dry fly like a Trout. From the standpoint of fly-fishing this is the best sporting fish in the Prairie Provinces.

The following animals were found in the stomachs of goldeye from Lake Winnipeg: larvae of *Sialis sp.*, *Hexagenia limbata occulta*, and other *Ephemeridae*, *Tanypinae*, *Chironominae*, *Phryganeidae*, *Libellulidae*, aquatic and terrestrial *Coleoptera*, *Corixa sp.*, *Daphnia longispina*, *Ostracoda*, *Mysis relicta*, *Estheria mexicana* and remains of small fishes.

The average weight of the goldeye of the Prairie Lakes varies between one half and three quarter pounds. The rate of growth of goldeye is as follows:

Age in Years	Length in mm.
1	100
2	150
3	205
4	230
5	290
6	330
7	345

Very little is known about the spawning habits of the goldeye in this region, but undoubtedly this is an early spring spawning fish.

As has been indicated, most of the goldeye are consumed as a smoked product in the local markets. The best smoked product is obtained from frozen fish. For this purpose the fish, after dressing, are put into brine for several hours, artificially stained to produce a golden color and smoked for several hours in hot smoke. For smoking the fuel used is poplar wood with oak sawdust. The fish are hung on iron wires through the eyes. The local price in Winnipeg for smoked goldeye is about 27¢ per pound.

The species is not artificially propagated in the Prairie Lakes and no experiments along this line have been attempted.

The name "Goldeye" is due to their golden colored eyes, and the author was astonished when, during a dark night, he was lifting gill nets containing this fish, by flashlight, the eyes were so bright and fluorescent that it is almost impossible to describe this remarkable phenomenon.

Sturgeon (Acipenser Fulvescens) (Rafinesque)

The lake sturgeon is common in many parts of the Lake Winnipeg system, e.g., Lake of the Woods, Winnipeg River, Saskatchewan River and among the granite rocks of the eastern shore of Lake Winnipeg. It also occurs in the Red River and the Assiniboine. On the other hand it is practically absent from the western shores of Lake Winnipeg and from Lakes Manitoba, Winnipegosis, Dauphin and St. Martin. During the past ten years one small sturgeon has been caught in Lake Winnipegosis and another in Lake Manitoba near the mouth of the Fairford River. It may be noted that lake sturgeon seem to prefer water which is not strongly alkaline (pH value of not more than 8.2).

The following are the figures concerning the sturgeon production in the Province of Manitoba during the years from 1921 to 1927 inclusive (A. Bajkov and F. Neave 6).

1921	57,200 lbs.
1922	87,400 lbs.
1923	117,000 lbs.
1924	235,900 lbs.
1925	167,700 lbs.
1926	108,000 lbs.
1927	82,000 lbs.

It will be seen that the first four years show a gradual increase in production and might lead to the conclusion that the fish were gaining ground. Such, however, is not the case, but rather that they were not fished for as heavily in these earlier years. The Armstrong Independent Company had a very large outfit on the Nelson River in 1924–25, which accounts for the large production in these years. From then on, with relatively the same outfits, both on the Nelson,

the Big Saskatchewan and Lake Winnipeg, production has decreased. Of the totals given above, about one-third represents the productivity of Lake Winnipeg.

Sturgeon fishing in Lake Winnipeg is prohibited at the present time. It has been carried on in the past chiefly by Indians and Icelandic fishermen, by means of gill nets and night lines. The nets had a legal mesh of 12 inches extension measure. Night lines were commonly baited with sucker meat, slightly salted, and crayfish.

These lines were often very successful and in some localities a line bearing 300 hooks gave an average yield of 8 large sturgeons per day. This is good evidence of the local abundance of the fish. The process of dressing the fish (i.e. removal of the head, fins and viscera) reduces the weight by about one quarter. The viscera are used as food by the Indians. The meat and caviar were shipped mainly to the United States. The prices at Berens River in 1927 were: Meat about 40 cents per pound, caviar $1.00 per pound.

The lake sturgeon reaches a length of 8 feet and a weight of 300 lbs. (Koelz, Fishing Industry of the Great Lakes, Fig. 7), the heaviest fish being usually females.

Unlike most other species of the genus, *Acipenser fulvescens* is reputed to be wholly a fresh water fish. The following data concerning the breeding were obtained during vists to Winnipeg and Berens Rivers in 1927 and Pigeon River in 1928 and 1929. The spawning season extends from about the middle of May to the beginning of June. For this purpose it ascends rivers, only occasionally spawning in lakes. All the rivers flowing into the eastern side of Lake Winnipeg are visited by sturgeon, the eggs being deposited close to rapids or waterfalls. Perhaps the most important spawning grounds are situated in the Winnipeg River above Seven Sisters Falls. In Berens River the fish do not ascend beyond the first waterfall which is about 40 feet high and presents an impassible barrier. Spawning usually takes place in about 10 feet of water on hard stony or gravelly bottom. The ripe eggs are about 3 mm. in diameter and dark grey in colour. Few fish spawn before reaching an age of 25, and often not until 30 or 40 years old (30–40 lbs. weight). After the female has reached the spawning age, the number of eggs shows a great increase at each subsequent spawning. Breeding does not take place every year, as is indicated by the fact that large females often show only very small, unripe eggs at the proper season.

The fry hatch after about 2 weeks and frequent shallow bays where the current is not too swift. A young fish on June 22nd, near Seven Sisters Falls, Winnipeg River, was about 3 cm. in length, but this year the season was more than usually advanced.

In Lake Winnipeg large sturgeon were caught in shallow water (4–5 feet) in June, but later in the Summer in deeper places (in August about 7 fathoms). In the Winnipeg River they occur at all depths from 1 or 2 feet near shore, where they seek food amongst wild rice

(*Zisania aquatica L*) to the deepest parts of the river. There is some evidence that the fish breeding in shallow water tend to be of a darker colour, with blunter snouts, than those living in the deeper parts. In winter they lie in schools in the deepest holes, a habit shared by most other species of sturgeon. Though in general the sturgeon feeds at the bottom, in fine weather it often rises to the surface and frequently jumps, sometimes to a height of 7 feet above the water. This action was observed on the Winnipeg and other rivers.

It is evident from the results of the examination of the alimentary tracts of sturgeon, that immature insects form the largest items of food of this fish. The larvae of "Fish-fly" (*Hexagenia limbata*) is by far the most important single form. Mollusks and crayfish are next in importance, the former by reason of the large numbers obtained, the latter because of the large size of some of the individuals. It appears probable, on the other hand, that a certain number of the mollusks included herein had been swallowed as dead shells together with sand and mud and hence should not really be counted as items in the food. An examination of the alimentary tracts of whitefish from Lake Winnipeg indicates that this fish feeds to a large extent upon similar food to the sturgeon, but in general the two fishes do not frequent the same areas.

The growth rate of the sturgeon is very slow. At the age of twenty years the fish is commonly a length of about one metre. After this, increase in length takes place very slowly but in weight much more rapidly. The approximate ages of the fishes examined were determined by otoliths.

The exact age of very old sturgeon is very difficult to determine but undoubtedly fish may live to be more than a hundred years old. (In Russia several specimens of *Acipenser guldenstadti* have been caught bearing gold rings placed on them more than one hundred years previously.)

It is difficult or impossible to construct a graph showing the increase in weight as the fish grows older, owing to the fact that the females probably lose a third of their weight after spawning. The loss in weight is not wholly represented by the deposition of the roe, but is also due to the loss of a large amount of fat at such seasons. It requires at least one summer to recover the lost weight. In the Winnipeg River in August some of the females were in fine condition with large ovaries, and appeared ready to spawn in the following spring. Others were very thin and contained a few shrivelled eggs, having evidently spawned in the preceding spring and not yet recovered condition. The ovaries of these fish were very small.

Slow-growing and seldom spawning before the age of twenty-five years, the sturgeon in Lake Winnipeg have to be rigidly protected, if extinction is to be prevented.

The species is not artifically propagated in the Prairie Provinces, but as shown by a few experiments in Lake Winnipeg and extensive

experiments in Russia, it is possible to hatch this species artificially, if enough ripe males and females can be obtained at the right time.

Pike Perch or Pickerel (*Lucioperca* (*Stizostedion*) *Vitreum*) (Mitch.)

The pickerel ranks with whitefish and tullibee as one of the most important commercial species of the Prairie Provinces.

The annual production for Manitoba alone averages ten million pounds, half of this amount being obtained from Lake Winnipeg. The other two provinces together produce about one million pounds yearly. The product is known mostly as "Pickerel fillets."

This is probably the most widely distributed species, being present in nearly all lakes and rivers in the prairie region.

The average weight of the fish in catches varies between two and three pounds, exceptional specimens up to nine and even ten pounds being caught. The main bulk of the catches consists of fish between four and nine years old. The following table shows the average growth of pickerel in prairie lakes.

Age in Years	Average Length in mm.
1	160
2	230
3	290
4	330
5	360
6	390
7	415
8	430
9	435
10	443

From the examination of their stomachs it is evident that pickerel feed periodically and that the daily consumption is somewhat less than that of whitefish. Many stomachs examined were empty.

Pickerel fry during the first month are plankton feeders (main items are different planktonic *Crustacea*), but shortly after this they begin to feed on different insect larvae and small fish. The main food items of adult pickerel are small fishes, larvae of *Ephemeridae*, *Phryganeidae*, *Odonata*, etc., also amphipods, decapods and other crustacean are not rare.

The spawning period of pickerel in Lakes Winnipeg and Manitoba is usually at the end of April and beginning of May, although in the northern portion of Lake Winnipeg fish with ripe gonads were found in the middle of June. Pickerel spawn in shallow bays near the shore and most of them enter small creeks and rivers for spawning. The percentage of mortality of fertilized eggs and fry is undoubtedly more in pickerel than in whitefish, because the number of eggs in the former species is very much larger.

The incubation period of pickerel eggs is comparatively short,

being from one to two weeks according to the water temperature. Cannibalism often occurs among the pickerel fry, especially if there is a lack of food. The fry usually keep in schools in comparatively shallow places.

This species is protected by regulation of mesh of the gill nets, by a closed season and is also artificially propagated. A few years ago the Department erected a new hatchery at Lake Manitoba, specially for pickerel propagation.

SAUGER (*Luciperca* (*Stizostedion*) *Canadense*) (Smith)

This species, although extremely abundant in Lake Winnipeg, Lake Winnipegosis and other lakes, is not so important from the standpoint of the fish industry as the previous representative of the same genus, due to its comparatively small size. As most of the saugers pass through the larger size mesh of gill nets, the production of this fish for Manitoba is only about a quarter of a million pounds per year, most of them being caught in Lake Winnipeg.

The average weight of this fish is less than one pound. The rates of growth are as follows:

Age in Years	Average Length in mm.
1	90
2	160
3	220
4	260
5	280
6	310
7	340
8	360
9	370
10	380

The main bulk of fish in catches consists of specimens over five years old. The food of this species is more variable than that of the pickerel.

The following animals were found in the stomachs of saugers: remains of fish, larvae of *Hexagenia limbata* and *Hexagenia rigida*, larvae of *Chironomidae*, also *Amphipoda*, *Mysis relicta*, fish eggs, etc.

As this species has not much commercial value it is not propagated artificially.

YELLOW PERCH (*Perca Flavescens*) (Mitch.)

The production of perch in Manitoba is about the same as that of the preceding species, most of them being caught from Lake Manitoba during the winter time. The species is not of great commercial importance, but has some value as an angler's fish for local consumption.

The rates of growth of perch from Lake Winnipeg are given in the following table:

Age in Years	Average Length in mm.
1	70
2	140
3	200
4	250
5	300
6	320
7	330

Its food consists of small fishes, larvae of *Hexagenia rigida*, *Hexagenia limbata*, *Phryganeidae*, *Leptoceridae*, *Libellulidae*, *Corixa*, *Dytiscidae*, etc., small amphipods, *Mysis relicta* and small mollusks.

This fish is a spring spawner, laying its eggs on the aquatic plants. The fry are hatched in great numbers and serve as food for other carnivorous fishes. It has been found that this fish, occupying chiefly shallower places near the shore, destroys whitefish and tullibee spawn and undoubtedly the fry themselves during the earlier hatching periods.

The daily consumption of food by this species is somewhat higher than sauger and probably pickerel, as the stomachs of perch nearly always are full of different food. On the other hand the rate of growth is very much slower than other fishes among the commercial species. From this point of view, perch is not such an interesting fish for artificial propagation and is propagated only in small lakes which are not suitable for pickerel. However the prices on perch are somewhat higher than those of the two previous species.

It is interesting to note that the percentage of females among the perch is very much higher than males.

Pike (*Esox Lucius* Linné)

The pike, or as it is commonly called in the prairies, jackfish, is one of the most widely distributed species around the whole northern hemisphere. It occupies nearly all the waters of the Prairie Provinces being distributed from the United States up to very far north.

The annual production of this fish for Manitoba averages about four million pounds, for Saskatchewan about four hundred thousand pounds and for Alberta over one million pounds. It reaches a fairly large size and specimens of twenty pounds are still found in many localities. This is a very cheap fish, the fishermen's prices being between two and three cents per pound. Most of the pike are consumed by local population. Together with pickerel and perch this fish has a great sporting value for prairie anglers.

This fish grows very much faster than other species and the rate of growth is as follows:

Age in Years	Average Length in mm.
1	200
2	340
3	400
4	470
5	540
6	560
7	630
8	650
9	680
10	700

Jackfish feed chiefly on other fish and fry and crayfish, but often when there is a lack of food it takes also different insect larvae such as *Odonata*, etc.

The spawning period of this fish is early spring. Often they spawn under the ice in shallow places. The fry hatch after several days, depending on temperature of the water, and keep apart from one another.

The species is not artificially propagated.

The Suckers

There are quite a number of representatives of the sucker family (*Catostomidae*) in the Prairie Provinces. The most important of them being the northern sucker (*Catostomusc atostomus*, Forster) and the common sucker (*Catostomus commersonnii*, Lacépède), the former species being associated with whitefish in the northern deeper portions of Lakes Winnipeg and Winnipegosis, the latter more commonly in the shallower southern portions of the above-mentioned lakes as well as in Lake Manitoba. The common sucker is also widely distributed in certain alkaline lakes of Saskatchewan, being there the most important commercial species.

In the fisheries industry they are known under the name "Mullets" and are of secondary importance. However the production of this fish in Manitoba is over one million pounds per year, in Saskatchewan over a quarter of a million, and in Alberta over one hundred thousand pounds. The price of this fish is very low and it is consumed chiefly on the local markets. This fish is utilized mostly in winter.

Suckers caught during the summer have no market value and are used as food for dogs or else not utilized. However the flesh of the suckers, especially the northern one, is of good flavour, has not many bones and can be utilized as a can product. Also there is an opportunity for the future, in connection with the exhaustion of the soil in many farming districts, utilizing the mullets together with other fish offal, as this is a high class fertilizing material.

They are to some extent competitors with other commercial fishes being feeders on plankton, small amphipods, mollusks and insect larvae. There are indications in the fish-culture literature that

suckers destroy whitefish eggs. All these suggestions must be strongly criticized. The writer has carefully examined one hundred sucker stomachs from whitefish spawning grounds in the southern portion of Lake Winnipegosis during the spawning time of the whitefish, and for two weeks afterwards. No whitefish eggs have been observed in the stomachs of these suckers. Several stomachs of suckers were examined from different spawning grounds in other lakes and no whitefish spawn has been found.

Catfishes

Two species of this family might be mentioned in our account, these are the spotted catfish (*Ictalurus punctatus* Rafinesque) and common bullhead (*Ameiurus nebulosus* Le Sueur). They are distributed in the Lake Winnipeg system and the former is of some commercial value, its annual production averaging over one hundred thousand pounds. It is very common in all the eastern tributaries of Lake Winnipeg, the Red and Assiniboine Rivers. Reaching up to twenty pounds this fish is also to some extent a game fish. The meat of this fish has a good flavour. They feed mostly on small fish, vegetable matter, mollusks, etc. The second species is distributed in shallow bays and swampy places, has no commercial value and is utilized mostly as food for dogs. The food of the Bullhead consists of small fishes, mollusks, amphipods, fish eggs and vegetable matter.

Lake Trout (*Cristivomer Namaycush*) (Walbaum)

This deep water fish is entirely absent from most of the shallow prairie lakes. It does not occur at all in Lakes Winnipegosis, Manitoba, Dauphin, Waterhen, etc., and only a few individuals are caught occasionally in whitefish nets in the northern portion of Lake Winnipeg. They are distributed mostly north of Lake Winnipeg in the lakes which we placed in the third category. All the Lake trout in Manitoba are obtained from the Pas district and the annual catch is a little over one hundred thousand pounds only. In the western prairie provinces the production of Lake trout is higher, being in Saskatchewan about 270,000 pounds and in Alberta over one million pounds. We have no data concerning the rates of growth of this species. The main bulk of its food consists of small fishes, mostly tullibees and cisco.

Speckled Trout (*Salvelinus Fontinalis*) (Mitch)

This eastern trout occurs only in creeks and rivers in the northern Manitoba region. It is fairly common in the streams entering Hudson's Bay. This fish has no commercial value at all, being captured only by anglers.

The species was artificially introduced by the Department into certain lakes of Jasper National Park in Alberta, where previously there were no fish. A result exceeding all previous experiments of

this kind was obtained. Fish which usually reach maturity after four years grew to this size in sixteen months, spawned at this time and were present in such quantity, that after a few years it may be the best fishing place on the American continent.

There is one large sea-run trout (probably Greenland charr—*Salvelinus alpinus stagnalis*, Fabricius) which enters the Churchill River, but it has not yet, at any rate, any commercial value. Also, in the mountain streams and lakes of Alberta occur three excellent game fish namely Rainbow trout (*Salmo irideus*, Gibbons), Dolly Varden trout (*Salvelinus alpinus malma*, Walbaum) and Cutthroat (*Salmo clarkii*, Richardson).

Other Fishes

There are several other species in this region which have little or no commercial value, as for instance the Sheepshead (*Aplodinotus grunniens*, Rafinesque) and Rock bass (*Ambloplites rupestris*, Rafinesque). The first has a small market in Winnipeg; the second one is known in certain localities as a game fish.

Another species which is very abundant in the prairie provinces is the Ling (*Lota lota maculosa*, Le Sueur). This species is caught in great quantity, has no value at all and the fishermen do not even feed this fish to their dogs. However it might be at least utilized as fertilizing material.

Scientific Investigations in Connection with the Fisheries Problems

The main problem of such investigations is to determine those specific conditions under which productiveness on one side and resisting forces on the other keep the fish population in balance.

Therefore, examinations of hydrological and hydrobiological conditions, rates of growth and food of fry should be a first consideration.

Detailed investigations of the most important commercial species are being carried on at the present time in order:

1. To obtain data of total amount of fish food in the lakes.
2. Daily consumption of food by each particular species.
3. To estimate the fish population, i.e. approximate number of individuals of every commercial species.
4. To find average number of fish which can feed in certain areas.
5. To estimate the number of fertilized eggs deposited by each species under natural conditions and their mortality.
6. To estimate the number of fry of each commercial species hatched every year under natural conditions and their mortality.
7. To estimate the maximum amount of fish which can be taken from the lakes every year without lowering the balance of the fish population.
8. To find methods of protecting the fry hatched in the hatcheries from perishing.

Boats, Instruments and Methods, Etc.

For the investigation of Lake Winnipeg, the forty foot schooner *Breeze* with an auxiliary gasoline engine was purchased. (See Fig. 6.) Several other sail and row boats were used also during the period of investigations.

For measuring temperatures, several Negretti and Zambra reversing thermometers were used. For water samples, two bronze bottles with rubber stoppers were employed. For the measurements of light penetration, Secchi disks of 20cm. diameter were employed. The pH value was determined by the use of several Lamotte comparators with phenol red and other indicators. The dissolved oxygen content was usually determined by the Winkler method and of carbon dioxide by the Standard method of Titration with N/22 sodium carbonate solution with phenolphthalein as indicator. For the study of the currents in Lake Winnipeg the standard drifting bottles were employed. Qualitative plankton samples were collected at the surface and in deep water at many points in all lakes examined by means of horizontal and vertical tows. The stomach contents of many specimens of different fishes and fish fry yielded much valuable data.

All plankton for quantitative work was collected with three special galvanized iron plankton cylinders, volume, ten litres each. These cylinders were each fitted with a lid and a bottom in the form of two semi-circles hinging in the middle and acting as valves, which open as the apparatus descends, allowing the water to pass freely, but close as soon as the cylinder stops or is drawn up. The water collected, usually 100 but never less than 30 litres, from the desired depth, was then strained through an Apstein plankton net and carefully drained from the bucket into vials. The time required to obtain a full set of samples at each station varied from one to two hours (longer in very deep water). In deep places a special counting machine and a steel line were used. Special care was taken with surface samples to avoid taking them where previous sampling had disturbed the water. All plankton was preserved in 3 per cent formalin. Temperatures were always taken with plankton samples at all depths. Water samples for determination of oxygen were taken when possible at the same time.

The work with a cylinder apparatus, such as described, which cuts out a short vertical column of water at any point from surface to bottom with a minimum amount of disturbance, will always be very much better and more exact than the work with a pump, where water is pumped from different depths and then filtered through the plankton net.

For volumetric determination of plankton, use was made of special, graduated tubes in which the plankton was allowed to settle for 24 hours. These tubes were about half a metre in length with a diameter of 5 mm. The plankton was well shaken up before being placed in

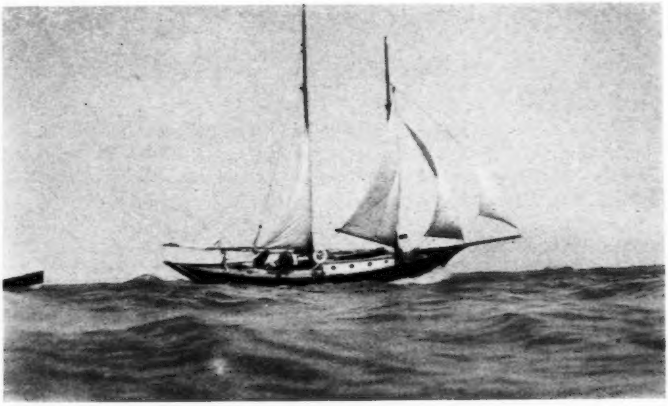


FIG. 6. Schooner *Breeze*.

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the settling tubes to ensure a thorough mixing of organisms of different specific gravities.

Several other experiments for separation of different animals by utilizing their different specific gravities (in NaCl solution) by washing out small diatoms from larger copepods and phyllopods were performed.

In connection with the study of the circulation of the organic and mineral matter, several chemical analyses of the most characteristic plankton samples, as well as of different species, have been made.

It was found that in Lake Winnipeg during the month of August are present approximately 5,512,500 cubic metres of plankton containing approximately:

1,147,500,000 kg of rough weight,
114,750,000 kg dry weight,
76,500,000 kg organic matter,
38,250,000 kg mineral salts,
30% ash in dry weight

For bottom fauna two Ekman dredges (9 and 12 inches square) as well as several different (1-3′) simple zo-ological dredges were used.

Samples were washed through metal sieves and riddles. The most convenient sieves were found to be 2½ feet in diameter with 1/20 inch mesh. After washing, all organisms were carefully collected into vials and preserved in alcohol or formalin, or counted and recorded.

The material was worked through in the Prairie Lakes Investigation Laboratory in Winnipeg, where all bottom organisms were counted and identified, and the "rough weight" of certain species was determined.

As samples of the work carried out on the productivity of the Lake Winnipeg bottom we submit the following results:

1928

Species	Thousands per sq. mile	Rough Weight in Kilograms	Dry Weight in Kilograms	Organic Matter in Kilograms	Mineral Matter in Kilograms
Estheria mexicana	32,900	2,211.0	182.4	166.05	16.35
Amphipoda	595,020	19,634.6	6,515.47	6,475.72	39.75
Mysis relicta	13,630	219.6	44.8	40.32	4.48
Hexagenia limbata	96,820	7,674.5	1,696.0	1,383.69	312.31
Phryganeidae	46.530	3,615.2	903.8	450.0	453.8
Chironomidae	39,890	780.0	312.0	215.28	96.72
Mollusks	130,190	3,120.0	60.04	17.4	42.65
Total	954,980	37,255.0	9,714.5	8,748.46	966.06

1929

Species	Thousands per sq. mile	Rough Weight in Kilograms	Dry Weight in Kilograms	Organic Matter in Kilograms	Mineral Matter in Kilograms
Estheria mexicana	2,800	188.0	15.5	14.1	1.4
Amphipoda	647,000	21,400.0	7,100.0	7,060.0	40.0
Mysis relicta	1,200	19.4	4.0	3.6	0.4
Hexagenia limbata	230,000	18,250.0	4,030.0	3,290.0	740.0
Phryganeidae	19,000	1,472.0	368.0	178.0	190.0
Chironomidae	67,000	1,310.0	537.0	370.0	167.0
Mollusks	91,000	2,180.0	41.9	12.1	29.8
Total	1,058,000	44,819.4	12,098.4	10,927.8	1,168.6

Average amount of rough weight is 41.000 kg. per square mile.

As can be observed from the above tables the total number of different organisms and their dry weight, as well as organic and mineral matter in 1928, corresponds very well with that of 1929.

Counting the whole whitefish ground area in Lake Winnipeg as 8,000 square miles, we can say roughly that this bottom represents 328 million kilograms of whitefish food, containing about 60 million kilograms dry weight.

In connection with the Prairie Lakes Investigations, a small Biological Station was established on Lake Winnipeg by the Biological Board of Canada, this summer.

More than twenty visitors, mostly professors and students of the University of Manitoba and one from the United States, visited the station during the first month and a half of this season.

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TORONTO ANGLERS' ASSOCIATION

G. S. Bell

Chairman of Conservation Committee, Toronto Anglers' Association

On behalf of the Toronto Anglers' Association I have been requested to address your Society. Feeling that you will be interested in what we, as Anglers, are endeavoring to accomplish in the direction of fish conservation, I shall try to outline briefly what we are doing and what we hope to accomplish.

Our Association was started about five years ago and now has a membership of over two thousand. Soon after organization, we started to gather information in regard to fish conservation in the various states of the United States and other countries. We soon realized that our problem differed in many respects from those of other countries or states which were actively carrying on restocking and other measures of game fish conservation.

Ontario covers an area of 407,262 square miles, bordering on all the Great Lakes except Lake Michigan, and has some large inland lakes such as Nipigon, Nipissing and Simcoe, as well as thousands of smaller lakes and streams. The water area alone is approximately 50,000 square miles, which is about the total area of New York State. In the older part of the Province, which comprises, roughly, the territory for 100 or 150 miles north of Lake Ontario and Lake Erie, many of the waters have been depleted of game fish and, therefore, present a somewhat similar problem to New York or Michigan a few years ago. On the other hand, the rest of the Province, which is much the largest part, is still almost in its original state and gives us a wonderful opportunity to do something to prevent these practically unfished waters from being depleted.

In addition to our own Anglers, tourists are coming in increasing numbers each year and the toll of fish taken is naturally very heavy. If these undepleted waters should be allowed to reach a condition where it might be necessary for the Government to restock them, it would be an enormous task both as to labor and money and in the meantime the Province would lose a large part of its lucrative tourist traffic.

Owing to Ontario's large area, the efficient enforcement of the game fish laws naturally requires a large force of wardens, especially as many parts of the Province are as yet sparsely settled and means of communication are difficult.

Since until a few years ago very little had been done towards restocking our waters, the Toronto Anglers' Association, with other Anglers' Associations throughout the Province, requested the Government to appoint a committee to study the whole problem and to submit recommendations on which a comprehensive and good workable policy could be based. The Minister in charge of this Department, Hon. Charles McCrae, lent a sympathetic and comprehending ear

and appointed the requested committee. The report of this committee is now completed and we are assured that there will be ready shortly for distribution information of the greatest value in helping to conserve this wonderful heritage for all time.

Our Association is carrying on casting competitions and encouraging good sportsmanship. It has published several booklets on game fish and has conducted essay competitions on fish conservation in our schools, since one of the chief duties of an Anglers' Association is to influence public opinion and create an enlightened public sentiment as to the conservation of game fish.

Successful restocking can only be accomplished by having accurate knowledge of water, food, life histories of the fish and other biological data which can only be gained by trained scientists and fish culturists such as comprise your Society. In Ontario a start has been made in this direction, but we hope that the biological force soon will be considerably increased.

In conclusion, I wish to quote from a report of Evermann and Clark and also Dr. Kendall. The opinions expressed cannot be too often emphasized and indicate the way our Anglers' Association hopes that fish problems will be handled in the Province of Ontario:

"No stream or lake should be stocked with fish until it has been carefully studied by a competent biologist and found to possess the conditions or factors of favorable environment for the fish which it is proposed to introduce. Fish culturists should adopt this principle and adhere to it as an invariable policy.

"Know your lakes and streams; likewise know your fish; correlate the two and act accordingly. You cannot know the lake or stream without a thorough biological or ecological investigation; you cannot know the fish without a thorough study of its life history and habits, and you can no longer have fish without paying the price, in intelligence and funds, necessary to produce them.

"The formulation of constructive policies involves detailed, comprehensive, scientific studies of this resource, such as have already been most successfully conducted at research or educational institutions, rather than in connection with administrative departments of the various states."

"The problems demanding investigation are too complex and difficult to expect immediate solution all along the line. A sufficient technical staff should be available to permit part of it to be devoted to the continuous survey of the waters, and to problems involving more immediate attention, and the remainder of the staff to be devoted to other important problems, which require much more time for solution."

"The public should be made fully aware of the magnitude of the difficulties involved in an investigative program for fish, so that they will come to realize that to maintain this resource there must be a continuous, permanent program, one which can never be completed so long as the resource lasts, and so long as conditions change which influence the fish. Investigations must be as constant as taxes."

PAPER ON FISHWAYS

C. Bruce

Fisheries Engineer, Department of Fisheries, Ottawa, Canada

Up to the last ten or fifteen years the development of water powers on Canadian rivers may be said to have been carried on in a comparatively small way. Dams were usually of low heights and it was not usual that the power utilized the entire discharge of the river except during low water periods.

Under such conditions the problems in connection with the provision of a passage for fish were not usually very difficult.

With the development of water power by large interests on some of the principal fishing rivers of the country, involving in many instances the erection of dams of unprecedented heights, the question of providing a means for the ascent of migratory fishes in order that they may reach suitable spawning grounds has become one of some considerable importance.

The Fisheries Act, a Federal Statute under which the provision of fishways in Canada comes, contemplated that the owner of any slide, dam or obstruction shall, provided it has been determined to be necessary, by the Minister of Fisheries, that a fishway should exist, erect and maintain such fishway in an effective condition.

Obviously owners of dams would have as a rule little, if any, conception of the requirements for an efficient fishway, and it has accordingly been the policy to specify, through an Engineer of the Fisheries Department, the type of fishway to be built.

The underlying principle in the construction of a fishway is the reduction or retardation of the current velocity of the water at the dam to such an extent that fish may surmount it.

Several means have been used in different types of fishways to accomplish this, among which may be mentioned:

(1) The inclined plane system in which a series of deflecting baffles are so arranged in an inclined flume as to cause the water to descend in a long sinuous route.

(2) The pool and fall system in which the water is brought down to a lower level by a series of short falls with intervening pools.

(3) The counter current system in which the descending volume of water is checked by meeting an opposing current at certain intervals.

(4) The lock and gate system in which the higher or lower level is reached through one or more locks operated by gates.

(5) Of recent years some experiments have been made with lifts, the fish being confined in a box or basket and taken up over the crest of the dam by mechanical means.

Of the systems above outlined it is necessary for the purpose of this paper to deal with the second one only, that is the pool and fall

system, which in the writer's opinion provides the most efficient fishway.

In approaching the question of the location of a fishway certain physical conditions should be observed. Based on the knowledge that fish will adhere to the descending current, which it is their instinct to oppose in their ascent of a river, it is obvious that the lower end of a fishway should be located at a point near the foot of the dam or obstruction in which it is to be built. In other words the entrance should be at a point past which fish are unable to ascend by the natural river, so that they are in a sense "covered" and in seeking a means of ascent will be attracted to it by the outflowing water. In the writer's opinion the entrance should also be located, where such is feasible, slightly out of range of the heavy overfall of water from the dam in order that the smaller outflow from it will not be nullified and the attraction which it provides to fish lost. Too much importance cannot be placed on the location of the entrance as an otherwise efficient fishway may be rendered useless if it is not suitable.

Coming to the design of a fishway this may perhaps be divided for the purpose of description into two parts, firstly the inclined portion which surmounts the height to be overcome and secondly the "head" of entrance of the fishway into the dam itself.

The graded portion should be so arranged that when the partitions are placed the pools formed thereby will be of suitable dimensions to permit reasonable resting places without excessive turbulency and that the head between compartments will not be too great for the varieties of fish using it.

For dams of upwards of about eight or ten feet high the provision of quiet water compartments is probably not as important as it would be for those of greater heights as the ordinary varieties of fish can surmount such a height without the need of resting.

The writer has had good success in such fishways when built on a grade of one vertical to six horizontal with partitions arranged to provide a head of one foot between compartments.

For fishways surmounting dams of greater heights the writer has adopted a grade of one vertical to eight horizontal as the maximum that should be used. With partitions arranged to provide a head of one foot between compartments the turbulency is considerably reduced and an opportunity afforded for the fish to rest.

In designing fishways for rivers on the Atlantic coast it is usually necessary to provide for the ascent of alewives, a variety of herring which spawns in fresh water, and as it has been demonstrated that a head greater than one foot is difficult for them to negotiate. This has been generally adopted as the maximum.

Where salmon or trout only are concerned a head of two feet between compartments is not excessive.

The type of partition forming the compartments may be varied. For fishways surmounting low dams where the absence of turbulency

is not important, the writer has used a partition placed across the fishway provided with a notch at the top over which the water falls and a submerged orifice through which varieties of fish such as alewives may swim without leaping.

Where turbulency is to be eliminated as much as possible it is considered that the descent of water between compartments over a sloping apron or ramp, arranged between the side wall and a wing wall in the partition itself, is an improvement, and such arrangement has been adopted by the writer for the greater number of fishways built in recent years.

The width that a fishway should be built depends to some extent at least on the necessity for elimination of turbulency. For low dams the writer has used a width of from four to five feet with good results, but for higher dams this is usually increased to six or even eight and ten feet.

It is not considered that ordinarily the depth of water in the compartments of a fishway should be less than from two and one-half to three feet.

The head of the fishway where it passes into the dam should provide not only a means for admitting water but also a method whereby the quantity so admitted may be governed in order that the various compartments may be supplied with a relatively uniform flow.

In the majority of Canadian rivers the discharge varies greatly during different stages of water and the head in the dam may have a difference of as much as from three to five feet. Under such conditions a fishway would be flooded at some periods and insufficiently supplied at others unless a means of governing the flow were introduced.

It is considered desirable where such is feasible that the regulation of the flow into a fishway should be as nearly as possible automatic. This has been accomplished for variations up to about three feet by means of several compartments with openings through the partitions at the bottom, the dimensions of the openings being reduced in each successive partition starting at the upper end.

With such an arrangement the water entering the first compartment tends to rise to the same level as that above the dam, but as the next partition is provided with a somewhat smaller opening a portion of the water passes through it thereby lowering the head in the first compartment. This action is repeated in the next compartment and so on for the full number provided. The total head is thus stepped down and divided into series of lesser heads, none of which is too great for fish to negotiate in their passage through the submerged apertures.

A number of such automatic regulating heads are in use in fishways in Canada, but where the river is of considerable importance and the services of a guardian or attendant are forthcoming, the usual method of control is by means of a series of stop planks over which the water

passes and which may be regulated at will to suit the variations in head above the dam.

Some plans of fishways for dams in Scotland are shown equipped with a movable sill regulated by floats for governing the entrance of water. This is doubtless an excellent arrangement, but where ice conditions are as severe as those in Canadian rivers, consideration has not been given to it by the writer.

Materials for the construction of fishways may be either wood, concrete or stone according to the situation. The first named material while providing cheaper construction leads to more expensive maintenance costs as the life of a wooden structure is not usually more than about ten years and even before then portions of them may require renewal.

Among the fishways in operation in Canadian rivers providing for the ascent of fishes over dams of more than ordinary heights the following may be cited.

Gaspereau River, Nova Scotia:—Dam thirty-two feet high. The fishway is a wooden structure built in 1919, and renewed in 1929. The dimensions of the fishway are, width six feet, depth four feet, and grade one foot vertical to eight feet horizontal. This fishway has been in efficient operation since it was built providing for the ascent of both alewives and salmon.

Mersey River, Nova Scotia:—Dam fifty-nine feet high. The fishway is of stone and concrete arranged in excavation to conform with the contour of the ground on which it is built, the maximum grade being one foot vertical to eight feet horizontal. The inside width is eight feet and the depth to top of walls approximately four feet.

In the ascent are two level pools one of which is one hundred and thirty feet long and the other one hundred and fifteen feet, thus subdividing the total climb into three with ample resting pools between. Compartments of this fishway are arranged with a difference of level of eighteen inches, which with a grade of one in eight provides a length of twelve as the minimum for any compartment. The inlet or head of the fishway at the dam is regulated with a series of four adjustable stop-plank gates, by which means the amount of water entering can be governed to suit the elevation of the water in the head pond.

This fishway was operated during the present season and large numbers of salmon have ascended.

THE REACTIONS OF SOME SOCKEYE SALMON TO A POWER DAM

R. E. Foerster

Biological Board of Canada

An insidious encroachment of water power interests upon the salmon streams of the Pacific coast is by no means a new discovery. The spread of this menace has been long known to those concerned in the preservation of salmon and strenuous efforts are being put forth at every opportunity to prevent the gradual elimination of this valuable natural resource. As Professor Prince has stated, as early as 1913, and at a meeting of this Society, "Fishery authorities are practically agreed that the decline of salmon in most countries is due, more than to any other cause, to the blocking of rivers and lakes by dams, artificial barriers, etc. No one can doubt that overfishing, injury to spawning beds and fifty other unfavorable circumstances, have had small effect compared with the completely destructive character of dams and the like." By enlisting the services of competent engineers and fish culturists, efforts are being made to devise some means whereby these two antagonistic interests may be allowed to flourish and prosper without harm or hindrance to either.

In many situations where the water power and fishery interests conflict—by the erection of a high dam in a salmon stream—the problem is a clear-cut one, namely, to provide means for the ascent of the adult salmon and the descent of the sea-ward migrating young over the dam.

On the Alouette river, a tributary of the lower Fraser river in British Columbia, there is found a situation in which further circumstances are found which spell the doom of the salmon in this particular stream. Since the behaviour of these salmon, in their efforts to carry out their duty of propagation in spite of the obstruction in their natural path, varies from certain enunciated scientific rules and principles, the details of the situation are considered worthy of record.

The Alouette river flows into the Pitt river which in turn empties into the Fraser. Some distance above its mouth the Alouette forks into what are termed the North and South Alouette. On the North Alouette there are two falls approximately two miles above the junction which obstruct the further passage of salmon. On the South Alouette and at the outlet of Alouette lake a dam has been erected approximately six miles from the junction, which completely blocks the ascent of salmon to the lake.

The Alouette dam is purely a retaining wall and the water of the lake is directed by tunnel under a mountain at the upper end of the lake to turbines at Stave lake, some two hundred feet below the level of Alouette. In other words, the outflow from Alouette lake has been reversed and the former outlet, now dammed up, is used only in periods of high water.

The situation created by the dam is thus aggravated by the change in direction and location of the outflow. Supposing there is to be sufficient water and flow in the South Alouette to bring the returning salmon to the foot of the dam, no useful purpose would be served in constructing a fish ladder or otherwise aiding the fish into the lake, for, unless there could be assurance that a suitable flow over the dam would occur at the time of the spring migration to sea, the resulting migrants would be forced to remain in the lake or seek a passage through the tunnel and turbines at the upper end of the lake.

The behaviour of the returning Sockeye in the fall of 1929, and to some extent in 1930, seems most unorthodox and peculiar and presents a clue as to the methods to be adopted if this run of Sockeye is to be preserved.

During 1929 an abnormally low rainfall together with an exceptionally warm summer produced a condition of very low water and as the operation of the power plant at Alouette remained normal, a rapid recession of the water stored in the lake occurred—to the extent that the lake level fell far below the level of the dam. When the Sockeye returned to the Alouette river, then, they found the south fork of the river practically dry and inaccessible. They were forced to turn into the north fork. Here their ascent was impeded by a twenty-foot falls and for those that were able to surmount this impediment, an absolute obstruction in the shape of a fifty-foot falls was encountered four hundred yards beyond.

The majority of Sockeye congregated at the foot of the first falls and in the belief that some might find spawning grounds above, efforts were made to transfer some of the Sockeye over the falls by dip-net. It was soon found, however, that the transferred individuals fell back again over the falls and further work was discontinued. On July third, 1929, it is authoritatively estimated that about two thousand adult Sockeye were gathered below the falls. On July sixth they had disappeared entirely. They had not jumped the falls; few only were found dead in the river; and the only conclusion to be derived is that they had passed, of their own accord, completely out of this tributary—possibly ascending the Pitt river to the spawning grounds there.

Toward the end of May, 1930, it was reported that several thousand Sockeye salmon were congregated below the falls in the North Alouette. A visit to the area disclosed that the volume of the North Alouette was much reduced; very few Sockeye were present; a relatively much larger stream was running in the South Fork and practically all the Sockeye were milling about the foot of the dam.

Having in mind the unorthodox retreat of the Sockeye from the falls of the North Fork in 1929, an attempt was made to capture and tag a number of the adult migrants at the foot of the dam in order to trace, if possible, their further movements, particularly whether they left the Alouette and proceeded elsewhere. Unfortunately after

85 individuals were tagged, a period of wet weather set in producing a condition of very high water and it became impossible to reach the salmon in the stream.

As might be expected, the Sockeye kept continually leaping at the overflowing water from the dam and many were bruised and battered, eventually succumbing to their injuries. The changing volume of water in the river made impossible an estimate of the varying number of Sockeye collected at the dam, but it appeared that many individuals were retracing their path. None of the tagged fish were retaken nor observed leaping. Latest reports, however, do not confirm a mass migration down-stream as in 1929, but suggest that while a goodly number may have drifted down and out of the Alouette system, the majority reacted in the proper manner and spent their energies in a futile effort to surmount the spillway.

Two propositions suggest themselves as remedial measures. The first involves the holding and spawning of the fish below the dam with subsequent removal of eggs or retention and liberation of fingerlings in the Alouette river. It was found that the dead Sockeye had not reached maturity at the time of death and it remains an open question whether they would have reached a satisfactory state of maturity if held in artificial ponds at the side of the stream, whereby they could be successfully spawned. The second proposition would be the complete fencing of the main Alouette at its junction with the Pitt with a view to directing the fish to the spawning beds in Pitt river.

Rather than attempt experiments of this nature, however, the run of Sockeye to this river-system has been sacrificed and it is expected that in the very near future no Sockeye will be found in the Alouette river. A race of splendid Sockeye is being utterly exterminated in order that a hydro-electric company may prosper.

The suggestion has been made that the only equitable compromise in the conflict of fishery and hydro-electric interests lies in the apportioning of and reserving of certain streams for fisheries and other streams for hydro-electric development. The situation at Alouette river stands as mute evidence that it is high time that the authorities in charge of fisheries development and conservation should be accorded full authority to declare what streams shall be reserved for fisheries and what streams may be given over for hydro-electric projects.

A POSSIBLE CRITICAL FACTOR AFFECTING THE PRODUCTION OF TROUT IN SOME BRITISH COLUMBIA LAKES

J. R. DYMOND

University of Toronto

The trout considered in this paper is the Kamloops trout (Salmo kamloops Jordan), one of the rainbow trouts, using that term in its broader sense.

The Kamloops occurs throughout practically the whole of the interior of the province of British Columbia.* In large lakes such as Kootenay and Okanagan it reaches a weight of twenty to thirty pounds, but in smaller lakes and streams its maximum size is much less. Weight reached in lakes of three or four miles by one mile is four or five pounds, although the average in such lakes is much less.

Between some of these medium sized lakes there is a very striking difference in the productivity or number of trout which may be taken from them annually over a considerable period of years without seriously depleting them.

Paul lake near Kamloops has been fished rather intensively for many years, but still produces satisfactory numbers of good sized trout. Other lakes similar in size and general appearance when first fished produce plenty of good sized trout but soon become seriously depleted, and never recover, although, because of the poor fishing, they are never fished at all intensively.

The usual explanations offered for the depletion of game fishes will not account for the situation found in most of these lakes. They have not been polluted or affected by the clearing of the land for they are still surrounded by practically virgin conditions, nor do they lack food for trout, for some of them at least teem with the Kokinee or Kennerly's salmon (Oncorhynchus nerkakennerlyi), the land-locked sockeye salmon which in its four years of life reaches a length of seven or eight inches. These fish appear to be the staple food of the larger Kamloops trout in lakes where both species occur.

It seems natural to assume, therefore, that the cause of the low productivity of trout in lakes of the type here described has to do with their reproduction or the survival of the young up to a size at which they begin to eat fish. For the purpose of argument let us reduce our lake to the size of a small pond and assume that our pond teems with food suitable for seven inch trout but produces only enough food suitable for small trout to bring ten or twelve through their first year. Once the trout have got through this critical period there is plenty of food available to them. A pond of this kind would contain plenty of trout if it were not fished for a number of years, but if on beginning to fish it again, twenty fish a year were taken out it would soon show depletion. On the other hand, if the pond produced

*The Trout of British Columbia, by J. R. Dymond. Trans. Amer. Fish. Soc., 58: 71–77.

enough food suitable for small trout to bring twenty-five through their first year and there was plenty of food for older trout, twenty could be taken out per year without depleting the lake. It is therefore suggested that one of the factors limiting the production of trout in some British Columbia lakes is the amount of food suitable for young trout which the lake produces.

Paul Lake, a good trout lake, has been found to have a considerable area of shallow water, the bottom sloping off gradually from shore to a depth of thirty feet some distance out. From a depth of thirty feet the bottom drops off suddenly into quite deep water. The shallow water area is rich in Gammarus, insect larvae and other small organisms such as are eaten by small trout. The lakes in which the production of trout is low have generally been found to have steep shorelines, the water in most places dropping away suddenly to considerable depths. Many of these lakes as already stated support very large numbers of Kokinees but these fishes feed on the plankton of the open waters.

In thinking of the food available to trout in a lake or stream it is not enough to consider only the food suitable for larger fishes. Without such food of course we cannot have many or large trout but we may have a low productivity of trout in waters that produce plenty of trout food if this is mostly of a size suitable for larger trout and lacks a sufficient quantity of food required by the fish at a particular stage or size in their growth.

Let us suppose that scarcity of food for trout in the fry stage is the limiting factor in a particular body of water, then the planting of more fry may not improve the productivity of the lake, indeed it may lower it by increasing the competition among the fry for the already scanty food supply*.

The work of H. C. White, who is investigating, among other questions, the effect of planting different numbers of trout fry in equal stretches of a stream, is of interest in this connection. It is possible that the planting of fry in waters poor in their food might be advantageous in the case of trout and the opposite in the case of whitefish. The tiny organisms on which these young fish feed are like the manna supplied the children of Israel in the wilderness. They cannot be stored up. They are renewed from time to time and if they are not eaten they perish, but an excess of trout fry may serve as a storehouse of such food, serving as food for their brethren when other food is scarce.

The point of all this is that we must investigate these problems not only qualitatively, but quantitatively. It is not enough to know what trout eat at different periods of their lives, but we must know how much of such food trout waters contain at different times of the

*Hart (1930) has already suggested that this might be the result of planting whitefish fry in waters possessing insufficient food for young whitefish, and Bajkov (1930) has suggested that lack of food for fry may be one of the important limiting factors in whitefish production.

year and how many trout the supply will support. In the future it may be possible to increase the supply of whatever food is insufficient for the needs of the fish-population best suited to a particular body of water. At present the most promising method of increasing the production of trout in lakes which have a low productivity in spite of ample food for large trout is to rear trout under artificial or preferably semi-natural conditions to a size at which they can make use of the fish found so abundantly in most of these lakes.

Discussion

DR. HUNTSMAN: Do the sockeye take the young trout?

PROF. DYMOND: Unfortunately, as I have indicated, we have had no opportunity of investigating this point. I believe that the sockeye salmon, being a plankton feeder, does not interfere seriously with the young trout.

DR. HUNTSMAN: What about the reverse relation, the taking of the young sockeye by the trout?

PROF. DYMOND: The sockeye we have found in the trout stomachs are usually of good size, six to seven inches long.

DR. HUNTSMAN: Are the sockeye fry being taken at all by the smaller trout?

PROF. DYMOND: I have seldom found them in the trout stomachs. The sockeye that I referred to, of course, are the landlocked sockeye.

A CONVENIENT CONTAINER FOR FISH SPECIMENS

S. B. LOCKE

Regional Forest Inspector, U. S. Forest Service, Ogden, Utah

It is often difficult when in the field, particularly on trips not planned for collecting, to find containers for treating and shipping fish specimens. I have found that old automobile inner tubes, when not badly deteriorated, are excellent for this purpose.

A section of tube sufficiently long for the specimens to be handled is sealed at one end by folding the tube over a short distance, rolling it and wrapping it tightly with a rubber band made by cutting a short section from an end of the tube. The specimens may be treated with formalin in the receptacle thus formed, the open end being sealed as was the other, if desired. For shipment after treatment the liquid may be drained out and the open end sealed in the same way by folding and wrapping with a band cut from the tube. Although practically no liquid is left the fumes are retained to preserve the specimens. For this purpose the tubes of lighter rubber are preferable since it is difficult to fold and bind the ends of the heavy tubes to make them absolutely tight. The chief precaution is to see that during treatment the specimens are not crowded or fitted so tightly in the tubes that they become distorted or out of shape. For mailing purposes the sealed tubes should be wrapped with absorbent material so that in case some of the liquid escapes no damage will result. This method has been used in shipping specimens from Utah to the Atlantic coast for several years with excellent success except in a few cases where large specimens were crowded into too small a tube or several specimens were placed so close together that they acquired distorted shapes. If one desired to use these containers a number of times, they could be improved by having one end of the tube vulcanized.

EFFECT OF DROUGHT ON WILDLIFE

E. Lee LeCompte

State Game Warden of Maryland

Fish

The drought which has prevailed not only in the United States, but in Canada as well, during the Spring and Summer seasons of 1929 and 1930, has been especially detrimental to the wildlife of our continent. Many of you present are well aware of the great loss of wildfowl directly attributable to this cause, in Canada during the years of 1929 and 1930. Thousands upon thousands of small lakes dried up, especially in the breeding grounds of wildfowl. With the exception of the New England States, most of our Country has been subjected to the longest and most serious drought, during the spring and summer of 1930, ever known. Some of our largest inland waterways have been affected and the water has been the lowest on record. There has been a great loss of fish life in the Mississippi River and its tributaries.

The Potomac River, rising in Pennsylvania, forming a line between Maryland and West Virginia, running over rock beds, has been more seriously affected from the drought of 1930 than even the oldest inhabitants can remember. Sections of the Potomac have been absolutely arid of water, except in small pools. The tributaries of the river in a great many sections have become dry except for small pools. These small pools have formed sanctuaries for the fish. To conserve our game and fresh water fish supply, our field forces from July 1st to August 15th, as rapidly as a stream would dry up, have traversed the beds, located the pools in which the fish had taken refuge, and by the use of dip nets have removed the fish and transferred them to sections of the Potomac River where conditions were more nearly normal. Through this process, we have been able to rescue about 400,000 black bass, crappie, pike and suckers, ranging in size from two to eighteen inches. Some of the black bass which have been rescued weighed as much as three pounds, the larger fish apparently having followed the stream before the water receded.

In Pennsylvania and West Virginia, there has been a serious loss of trout due to drought. The brook and rainbow trout especially have been seriously affected from the resulting high temperature, and the majority of the States in the drought area have lost thousands of these fish. Droughts of long duration cause loss of vegetation in our streams, thus depleting the supply of food on which fish life depends.

Game Birds

Droughts also seriously affect wildlife by causing forest and field fires, the most disastrous menace to the conservation of wildlife. Forest fires, a great many of which occurred during the nesting season in May, burned over thousands upon thousands of acres of valuable forest lands. In a great many cases game birds and game animals

in these areas were entrapped, and the nests and eggs of not only ground nesting birds but song and insectivorous birds which nest in trees were destroyed.

The ruffed grouse, wild turkey, cotton-tail rabbit, squirrel and raccoon were the species mostly affected. During the period from July 14 to August 8, the thermometer registered from 90 to 105 degrees, and so great destruction was wrought through forest fires that it is estimated that on a portion of the Allegany Mountains in Allegany County, 18,000 acres of forest lands were burned over. Some of this territory had not been burned for the past fifty years. It will take at least five years to restore the foliage and undergrowth on these burnt areas, some of which have been burned to such an extent as to make them useless for game cover in the future.

Fur-bearing Animals

In States where the drought of 1929 and 1930 was most severe and long continued, the fur-bearing industry too has suffered. The muskrat, one of the most prolific fur-bearing animals and one which produces more revenue than other species, has been very seriously affected. Even in marsh areas, there has not been enough moisture to promote the growth of the aquatic plant life on which the muskrat feeds. This species showed a decrease during the 1929 and 1930 trapping seasons of at least 50%. Mothers bearing young were unable to take their brood to water and thousands of young muskrats died from lack of food and water. In sections where the tide ebbs and flows daily, conditions have been somewhat better and aquatic plant life has not suffered to the extent that it has on inland areas.

I recommend the method used in Maryland of transferring the fish from pools along streams which have dried up to points where there is sufficient quantities of water to take care of them.

THE PLANT AND ANIMAL FOOD OF THE FISHES OF BIG SANDY LAKE

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The purpose of this study was to determine the natural food of the small fishes in a lake. The material for this investigation was obtained at Big Sandy Lake, Aitken County, Minnesota, during the summer of 1927. The fishes were collected from thirty-eight stations on the lake and each station was visited at least once a month. The following species of fish were collected and examined. This list represents all known species from this lake with the exception of Leucichtys tullibee, Tullibee, which is present but no specimens were obtained.

Amia calva Linneaus—Bowfin, Dogfish, Mudfish	13	specimens
Catostomus commersonii (Lacepede)—Common Sucker	171	"
Moxostoma aureolum (Le Sueur)—Common Red Horse	7	"
Notemigonus crysoleucas (Mitchill)—Golden Shiner	2	"
Luxilus cornutus (Mitchill)—Shiner	146	"
Ameiurus nebulosus (Le Sueur)—Common Bullhead	38	"
Esox estor Le Sueur Pike, Northern Pike	52	"
Percopsis omiscomaycus (Walbaum)—Trout Perch, Sand Roller	34	"
Huro floridana (Le Sueur)—Large mouth Bass	1	"
Eupomotis gibbosus (Linneaus)—Common Sunfish	2	"
Ambloplites rupestris (Rafinesque)—Rock Bass	9	"
Pomoxis annularis Rafinesque—Crappie	68	"
Vigil pellucidus (Baird)—Sand Darter	1	"
Boleosoma nigrum (Rafinesque)—Johnnie Darter	114	"
Percina caprodes (Rafinesque)—Log Perch	148	"
Perca flavescens (Mitchill)—Yellow Perch	298	"
Stizostedion vitreum (Mitchill)—Wall-eye, Pike Perch	54	"
Cottus ictalops (Rafinesque)—Miller's Thumb	42	"
Lota maculosa (Le Sueur)—Lawyer	4	"

One slide was made from the content of the stomach and another from the intestine of each fish examined. An estimate was made of what part the material on the slide represented of the entire content. In most cases, it was the entire content. Final results are estimations of the entire content of the stomach and intestine based upon the content, plant and animal, found upon the slide. The lengths of the fishes are given in millimeters and exclude the caudal fin.

Amia calva Linneaus—Bowfin, Dogfish, Mudfish — 13 fish examined
Size: 73–120 mm.

Digestive tracts of the 13 fish were empty.

Catostomus commersonii (*Lacepede*)—Common Sucker — 171 fish examined
Size: 15–95 mm.

Stomachs of 168 fish were empty. Stomachs of three fish contained:

ANIMAL FOOD

Johnnie Darter	1
Cladocera	4
Copepoda	2
Insecta	
Chironomus larvae	18

Intestines of 53 fish were empty. Intestines of 118 fish contained:

ALGAL FOOD

Microcystis	558
Coelosphaerium	93
Merismopedia	489
Gomphosphaeria	60
Oscillatoria	4
Gleotrichia	19
Navicula	165
Cymbella	23
Melosira	110
Volvox	26
Sphaerocystis	22
Pediastrum	22
Scenedesmus	16
Closterium	100
Cosmarium	6
Cylindrocapsa	21
Bulbochaete	3

ANIMAL FOOD

Protozoa	554
Rotatoria	1959
Parasites	10
Hirudineae	8
Mollusca	2
Hydracarina	15
Cladocera	1788
Copepoda	1783
Ostracoda	1143
Insecta	34
Chironomus larvae	528
Chironomus pupae	8
Copepoda larvae	113
Eggs	xx

Entomostraca were the dominant food in the fishes in this size, 15–90 mm. Rotatoria were numerous up until 50 mm., then a larger percentage of Chironomus larvae were consumed. Algal food was consumed in larger quantities when the fishes were less than 50 mm. in length.

Moxostoma aureolum (*Le Sueur*)—Common Red Horse 7 fish examined
Size: 90–125 mm.

Stomachs of 7 fish were empty. Intestines of 7 fish contained:

ALGAL FOOD

Gleotrichia	3

ANIMAL FOOD

Cladocera	195
Insecta	161
Chironomus larvae	749

Notemigonus crysoleucas (Mitchill)—Golden Shiner 2 fish examined
Size: 65–73 mm.

Stomach of 1 fish empty. Stomach of 1 fish contained:

ANIMAL FOOD

Cladocera	4
Insecta	1

Intestines of 2 fish contained:

Cladocera	10
Insecta	20

Luxilus cornutus (Mitchill)—Shiner 146 fish examined
Size: 10–95 mm.

Stomachs of 141 fish were empty. Stomachs of 5 fish contained:

ALGAL FOOD

Aphanizomonon	4000

ANIMAL FOOD

Insecta	3
Chironomus larvae	14

Intestines of 112 fish were empty.		Intestines of 34 fish contained:	
Microcystis	3	Rotatoria	75
Coelosphaerium	7	Hirudineae	1
Pediastrum	5	Hydracarina	1
Closterium	15	Cladocera	157
		Copepoda	15
		Insecta	163
		Chironomus larvae	14

Chironomus larvae and insecta were the dominant forms of food throughout the fishes represented in this size range.

Ameiurus nebulosus (*Le Sueur*)—Common Bullhead 38 fish examined
Size: 17–82 mm.

Stomachs of 26 fish were empty.		Stomachs of 12 fish contained:	
ALGAL FOOD		ANIMAL FOOD	
Bulbochaete	2	Gladocera	3
		Copepoda	5
		Malacostraca	3
		Insecta	10
		Chironomus larvae	56
		Chironomus pupae	4

Intestines of 27 fish were empty.		Intestines of 11 fish contained:	
Microcystis	13	Trematoda	5
Anabaena	1	Malacostraca	2
Pediastrum	1	Ostracoda	19
Spirogyra	10	Parasite	1
Oedogonium	5	Cladocera	49
Bulbochaete	4	Copepoda	15
		Insecta	
		Chironomus larvae	61

Entomostraca and Chironomus larvae were utilized as food by the fishes of the various lengths.

Esox estor (*Le Sueur*)—Pike, Northern Pike 52 fish examined
Size: 62–620 mm.

Stomachs of 15 fish were empty.	Stomachs of 37 fish contained:	
	ANIMAL FOOD	
	Fish	24
	Shiner	9
	Yellow Perch	16
	Johnnie Darter	16
	Log Perch	7
	Wall eye Pike	2

Intestines of 52 fish were empty except that 1 intestine contained 3 parasites. Northern Pike ate other fishes when small and throughout their life.

Percopsis omiscomaycus (*Walbaum*)—Trout Perch, Sand Roller 34 fish examined
Size: 44–75 mm.

Stomachs of 21 fish were empty.		Stomachs of 13 fish contained:	
ALGAL FOOD		ANIMAL FOOD	
Microcystis	50	Insecta	
		Chironomus larvae	93

Intestines of 28 fish were empty.	Intestines of 6 fish contained:	
	Insecta	15
	Chironomus larvae	17

Huro floridana (*Le Sueur*)—Large mouth Bass — 1 fish examined
Size: 85 mm.

Stomach of 1 fish contained:

	ANIMAL FOOD	
	Insecta	
	Chironomus larvae	3

Intestine of 1 fish contained:

	Parasites	3
	Insecta	6
	Chironomus larvae	3

Eupomotis gibbosus (*Linneaus*)—Common Sunfish — 2 fish examined
Size: 18–19 mm.

Stomach of 1 fish was empty. Stomach of 1 fish contained:

	ANIMAL FOOD	
	Insecta	
	Chironomus larvae	3

Intestines of 2 fish empty.

Ambloplites rupestris (*Rafinesque*)—Rock Bass — 9 fish examined
Size: 23–135 mm.

Stomachs of 6 fish were empty. Stomachs of 3 fish contained:

ALGAL FOOD		ANIMAL FOOD	
Coelosphaerium	1	Malacostraca	10
		Parasite	1
		Insecta	9
		Chironomus larvae	172
		Chironomus pupae	66

Intestines of 5 fish were empty. Intestines of 4 fish contained:

Microcystis	4	Cladocera	1
Coelosphaerium	1	Copepoda	3
		Insecta	43
		Chironomus larvae	19

Rock Bass from 23–35 mm. consumed algae and entomostraca, but between 80–135 mm. mostly Chironomus larvae.

Pomoxis annularis Rafinesque—White Crappie — 68 fish examined
Size: 20–75 mm.

Stomachs of 25 fish were empty. Stomachs of 43 fish contained:

ALGAL FOOD		ANIMAL FOOD	
Microcystis	1	Malacostraca	7
		Cladocera	1312
		Copepoda	1652
		Insecta	33
		Chironomus larvae	103

Intestines of 52 fish were empty. Intestines of 16 fish contained:

Microcystis	5	Cladocera	256
		Copepoda	61
		Nauplius larvae	31
		Insecta	21
		Chironomus larvae	33

The food of the Crappie between the sizes of 20–75 mm. was dominated by entomostraca. Chironomus larvae formed a larger percentage of the food at 75 mm. than when the fishes were smaller.

Vigil pellucidus (*Baird*)—Sand Darter — 1 fish examined
Size: 50 mm.

Stomach of 1 fish contained:

ANIMAL FOOD

Malacostraca	4
Insecta	1
Chironomus pupae	1

Intestine of 1 fish empty.

Boleosoma nigrum (*Rafinesque*)—Johnnie Darter — 114 fish examined
Size: 15–66 mm.

Stomachs of 77 fish were empty.

ALGAL FOOD

Stomachs of 37 fish contained:

ANIMAL FOOD

Malacostraca	1
Insecta	1
Chironomus larvae	69

Intestines of 93 fish were empty.

Microcystis	3
Coelosphaerium	1

Intestines of 21 fish contained:

Cladocera	2
Copepoda	9
Insecta	5
Chironomus larvae	71

Percina caprodes (*Rafinesque*)—Log Perch — 148 fish examined
Size: 25–80 mm.

Stomachs of 58 fish were empty.

ALGAL FOOD

Bulbochaete	5

Stomachs of 90 fish contained:

ANIMAL FOOD

Cladocera	360
Copepoda	99
Malacostraca	146
Insecta	84
Chironomus larvae	715
Chironomus pupae	20
Caddis fly larvae	1

Intestines of 111 fish were empty.

Coelosphaerium	2

Intestines of 37 fish contained:

Malacostraca	5
Cladocera	40
Copepoda	62
Parasites	7
Insecta	25
Chironomus larvae	175
Chironomus pupae	8

Entomostraca and Chironomus larvae were the dominant food between the sizes 25–50 mm. Few Entomostraca were consumed between 50–80 mm. At these sizes, the food consisted nearly entirely of Chironomus larvae with a few Insecta and Malacostraca.

Perca flavescens (*Mitchill*)—Yellow Perch — 298 fish examined
Size: 17–390 mm.

Stomachs of 159 fish were empty. Stomachs of 139 fish contained:

ANIMAL FOOD	
Malacostraca	71
Ostracoda	5
Hydracarina	7
Parasites	3
Crayfish	20
Fish	7
Cladocera	3243
Copepoda	1875
Insecta	229
Chironomus larvae	202
Chironomus pupae	15

Intestines of 249 fish were empty. Intestines of 49 fish contained:

Malacostraca	5
Hydracarina	11
Parasites	4
Cladocera	147
Copepoda	94
Insecta	159
Chironomus larvae	101
Chironomus pupae	5

Yellow Perch ate mostly Entomostraca between sizes 17–50 mm. Between 50–100 mm., the food was mostly Insects, and between 100–390 mm., it consisted of crayfish and fish. Chironomus larvae were eaten until the fish was 100 mm. long.

Stizostedion vitreum (*Mitchill*)—Wall-eye Pike 54 fish examined
Size: 52–380 mm.

Stomachs of 26 fish were empty. Stomachs of 28 fish contained:

PLANT FOOD		ANIMAL FOOD	
Potamogeton	mass	Fish	53
		Yellow Perch	1
		Insecta	30

Intestines of 52 fish were empty. Intestines of 2 fish contained:

Insecta	50

Insecta were eaten when the fishes were 75 mm. in size.

Cottus ictalops (*Rafinesque*)—Miller's Thumb 42 fish examined
Size: 20–62 mm.

Stomachs of 20 fish were empty. Stomachs of 22 fish contained:

ANIMAL FOOD	
Malacostraca	7
Insecta	22
Chironomus larvae	51
Chironomus pupae	11

Intestines of 30 fish were empty. Intestines of 12 fish contained:

Copepoda	2
Insecta	3
Chironomus larvae	22

Lota maculosa (*Le Sueur*)—Lawyer 4 fish examined
Size: 80–123 mm.

Stomach of 1 fish was empty. Stomachs of 3 fish contained:

ANIMAL FOOD	
Malacostraca	1
Insecta	11
Miller's Thumb	2

Intestines of 4 fish empty.

When the food of the specific fish differed at various sizes, this information was added in the notes of the fish in particular.

Summary

In this investigation 1,202 fish representing 19 species were examined. The food utilized by the fishes when they were less than six inches in length consisted of both plant and animal. This study emphasized the importance of the microscopic plant and animal life in the water and the insect larvae as the natural food of the various fishes.

The species of algae which have been utilized as food by the fishes in this investigation were as follows:

Microcystis flos-aquae (Wittrock) Kirchner
Coelosphaerium Nagelianum Unger
Anabaena flos-aquae (Lyngbye) de Brebisson
Merismopedia sp.
Gomphosphaeria sp.
Oscillatoria sp.
Gleotrichia echinulata (L. E. Smith) P. Richter
Navicula viridis Kg.
Cymbella affinis Kutzing
Melosira granulata Agardh
Volvox sp.
Sphaerocystis schroeteri Chodat
Pediastrum Boryanum (Turpin) Menegh
Scenedesmus sp.
Closterium acerosum (Schrank) Ehrenb.
Cosmarium sp.
Spirogyra sp.
Cylindrocapsa sp.
Oedogonium sp.
Bulbochaete sp.

WHAT MARYLAND IS DOING TO STOCK HER STREAMS

Swepson Earle

Conservation Commissioner of Maryland

The meetings of the American Fisheries Society and other organizations have done much to stimulate activity in the raising of fish and the stocking of the Nation's streams. Maryland has done more in the last few years to increase the supply of fish in the inland streams of the State as well as the Chesapeake Bay and its tributaries than ever before.

In 1927 the Maryland Legislature passed the State-wide anglers' license law, affecting all streams above tidewater. The revenue therefrom has produced sufficient funds to enable the Conservation Department to increase its hatchery facilities, to establish nurseries and rearing ponds where fish are reared to legal size before liberating, and to carry on a stream survey of the inland waters.

As a result of the planting of larger fish in the public streams, anglers during the trout fishing season of 1930 were able to get their creel limit in a half day's fishing. In conjunction with stocking of streams the survey which determines the suitability of a stream for certain kinds of fish, pollution, etc., has been very beneficial.

In a recent survey made by the Superintendent of Fish Hatcheries, it was found that the State had some 200,000 brook, rainbow and brown trout, ranging in size from 2 inches to 12 inches, in rearing ponds. Some 20,000 of this number are breeders, from which spawn will be taken this fall, and instead of being a purchaser of eggs to the extent of one or two thousand dollars the Department will probably be in a position to dispose of some eggs.

Through the co-operation of the U. S. Bureau of Fisheries and Mr. Lawrency Richey, seven rearing ponds were established on the latter's estate at Catoctin Manor in Frederick County, near the State fish hatchery at Lewistown. Fish have been successfully reared in these ponds, and the State receives fifty per cent of the fish for distribution in Maryland waters. The balance are distributed by the Bureau of Fisheries and Mr. Richey.

Maryland, like a number of other States along the Atlantic seaboard, has suffered extensive damage from the unusual drought which prevailed this summer. Many streams became very low and some completely dried up. It has been estimated by the Superintendent of Hatcheries that the Department lost 200,000 trout as a result of the dry weather. In some localities, where the streams were drying up and threatened great fish destruction, fish were seined out and placed in other streams which were amply supplied with water.

The Conservation Department is making a determined fight against pollution, and in this work the sportsmen's organizations are lending their full support. A sanitary survey of the waters of Chesapeake Bay has been carried on since 1925 with the assistance of the State

Department of Health. This safeguards the marketing of oysters, particularly, by zoning off any areas which are polluted and unsafe. The City of Baltimore has a $2,000,000 disposal plant for its wastes, and the waters of Chesapeake Bay are very free from pollution.

This safeguarding of the Chesapeake Bay waters plays an important part in the commercial fisheries of the Bay. After the oyster and crab fisheries, the Department ranks the fin fish as next in commercial value. During the past few years, through hatching stations established in various localities of the Bay, great numbers of the commercial varieties of fish have been turned out. During the spring of 1930, some 700,000,000 shad, herring and perch fry were liberated into the tributary waters of Chesapeake Bay.

THE PROBLEM OF THE CONSERVATION OF THE SOCKEYE SALMON IN BRITISH COLUMBIA

W. A. Clemens

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The sockeye salmon (*Oncorhynchus nerka* Walbaum), when canned, forms one of the most important fishery products of British Columbia. Its high oil content, the attractive colour of its flesh, its excellent flavour, its high nutritive value, all combine to make a canned product commanding a high market price. During the past ten years, 1920–1929 inclusive, the average pack in British Columbia has been 303,749 cases. The pack in 1929 amounted to approximately 281,000 cases having a value of over $4,500,000. In the years prior to 1916, when the Fraser river was so highly productive, the average annual yield of the Province was very much greater. The sockeye salmon has always been a valuable product and an important contribution to the wealth of the Province and the Dominion. It is evident therefore that the conservation of this natural resource merits serious consideration.

Life History

Before discussing the problems connected with the conservation of the sockeye salmon it is necessary to review briefly the life history of this species because an understanding of the life history is necessary for the appreciation of the problems. The sockeye enter various streams during the summer and fall on their spawning migration. They pass up those streams and tributaries on which there are lakes and pass through the lakes to spawn in the streams tributary to the lakes. They proceed to areas where the bottom of the stream is composed of gravel. The sexes pair off, the female clears a small area in the gravel and as the eggs are shed into the area, they are impregnated by the milt shed by the male. The eggs are gradually covered over with gravel and then the spawned-out fish drop down stream and die. The average number of eggs deposited by a female is approximately 4500. The period of incubation varies from three to six months depending upon the time of deposition and the temperature of the water.

The alevins make their way up through the gravel, gradually drop down stream with the current and eventually reach the lake. A few may pass through the lake and go down to sea as fry, but the great majority remain in the lake for a year and pass out to sea as yearlings. In some areas the young sockeye may remain two or even three years in the fresh water before migrating.

The life history in the ocean is not well known. Scale readings of migrating adults show that the majority spend two complete years in salt water, maturing in the third summer of sea life, therefore being four or five years of age depending upon whether they had spent one

or two years in fresh water. A considerable number may remain an additional year in the ocean and therefore mature at five or six years of age. Some individuals, particularly males, may remain only two years in the sea, maturing at three years. There is thus a rather wide variation in the number of years spent in both fresh and salt water. Little is known of the feeding areas in the ocean. The food of the few individuals caught in the open ocean has been found to consist largely of schizopods. The sockeye rarely take the troll and apparently live at some depth in the region of rather low temperature.

There is one further interesting point in connection with the life history, namely, that the individuals return with probably few exceptions to their parent streams. Marking experiments have fairly well established this for natural conditions. Information concerning returns in cases of transplantation is less definite.

The Problem

Stated broadly, the problem with respect to the conservation of the sockeye salmon is the establishment of a relation between catch and escapement. Production is dependent upon escapement. Too great catch with corresponding too small escapement means depletion. Too great an escapement may mean losses on the spawning beds or in the lakes and therefore may represent economic losses directly and indirectly to the fishermen. The problem therefore is to determine what escapement is necessary to maintain an area at a high state of production. The excess of individuals over the number required for this production should constitute the commercial catch. It is evident that the determination of the relationship between catch and escapement is a difficult task and will require many years of observation, experiment and study, but at the same time the solution is within the realms of possibility, in view of the fact that the salmon enter the streams to spawn and the determination of escapement, that is the number of spawning individuals, is possible. Until such time as adequate information is available recourse must be had in experimental regulation. Where there is evidence that a run to an area is not maintaining itself, the catch must be reduced to allow for greater escapement.

Regulations

As far as possible regulations governing the taking of sockeye salmon in the waters of the coast of British Columbia are designed to assure adequate escapements but many difficulties are encountered. Information concerning the sea routes taken by the salmon is meagre. Tagging of migrating individuals has yielded some useful information. For example, results from tagging at Seymour Narrows on the east coast of Vancouver island show that considerable numbers of sockeye pass along the east coast of Vancouver island on their way to the Fraser river. Regulations therefore designed to ensure adequate

escapements to the Fraser river must take into account the runs coming southward along the east coast of Vancouver island as well as those coming through the Strait of Juan de Fuca. Detailed knowledge of these movements is still lacking. It will be necessary to tag considerable numbers of fish almost daily throughout the entire fishing season at various points in order to determine the appearance and distribution of the various schools or races.

Lack of adequate information concerning the migration routes of the sockeye salmon is not the only difficulty in framing efficient regulatory measures. The fish do not respect international boundary lines. On their way to the Fraser river, for example, they pass through American waters. The conservation of the Fraser river sockeye is therefore of international concern, but up to the present time it has been impossible to bring about international co-operation in the matter of regulation of the catch. A somewhat similar situation exists with respect to the sockeye salmon proceeding to the Nass river in northern British Columbia. Results of tagging in Alaskan waters show that a considerable percentage of sockeye pass through Alaskan waters on their way to the spawning beds of the Nass river. In recent years the runs to this river have shown very serious decline, and international co-operation in developing adequate regulatory measures appears imperative.

Determined efforts along various lines are being made to obtain such information as may contribute to the solution of the problem of the conservation of the sockeye.

Tagging

In the attempt to determine migration routes, adults have been tagged where possible and where returns would be of significance. Since sockeye do not take the troll, only trap, seine and gill net fish are available. The first two types of gear are used to a very limited extent in British Columbia waters for the taking of sockeye, and gill nets are used in the mouths of the streams or in the area immediately outside. The opportunities for obtaining useful information are therefore limited. In 1912, tagging operations were carried out at the traps near Sooke on the south end of Vancouver island and the results showed that the sockeye entering the Strait of Juan de Fuca were bound for the Fraser river and indicated the routes taken through the State of Washington waters. In 1925, several hundred sockeye caught by purse seines in Deep Water bay along the east coast of Vancouver island were tagged and the results demonstrated that a portion of the Fraser river run comes down from the north through Johnstone Strait. These results show that captures far removed from a river have to be taken into account in the calculation of total annual catches.

In 1925, the operation of a trap at Haystack island off Portland inlet offered an opportunity for tagging. Of the returns, 60 per cent

were from the Nass river, but 13 per cent were from the Skeena river and 27 per cent from southeastern Alaska. The results thus indicate again the need for extensive information concerning the ocean movements.

Annual Analyses

In each year, the Provincial Fisheries Department collects data from random samplings of the runs to the four main river systems throughout the fishing season. The data consist of lengths, weights, sex and scales. This material is carefully studied and tabulated and the results provide a valuable record of the character and composition of the runs from year to year. Furthermore, the data, in conjunction with pack statistics and spawning bed reports, provide a basis for the prediction of the general extent of runs from year to year. It is evident that these predictions can at best be only approximate because practically no information is as yet available as to conditions on the streams during the incubation period or as to food and physico-chemical conditions in the lakes or in the sea. The development of the science of fishery conservation demands the continuous record of oceanographical and limnological data. Analysis of such data and of meteorological records should provide indications as to productivity from year to year.

Record of Escapements

As stated previously, accurate records of escapements are necessary if the relation between catch and escapement is to be determined. Each year more extensive and detailed reports on escapements are being made by Dominion and Provincial fishery officers and the information is very valuable. At Cultus lake on the lower Fraser river actual counts of the migrating adults are being made by the Biological Board of Canada and a similar procedure will have to be instituted in several other areas in order to provide adequate data. With accurate enumeration in certain localities and the development of a system of detailed reports, on escapements, spawning, and conditions during incubation periods, there will be accumulated a body of information upon which reliable judgment may be based as to annual production as far as the early life history stages are concerned.

Assistance to Natural Propagation

In conjunction with the attempts to establish and maintain adequate escapements, efforts should be made to improve stream conditions for spawning and incubation. Obstacles hindering the ascent of the fish should be removed or circumvented. In the Province of British Columbia the engineering staff of the Dominion Department of Fisheries gives special attention to the construction of fishways at falls and to the removal of serious log jams. In the case of the former an excellent example of the value of such work is afforded on Stamp river, where in some seasons of low stream flow the

salmon were unable to surmount the falls and died unspawned. The construction of a simple fishway now permits of the passage of the fish every year without difficulty. In the case of log jams it should be pointed out that all such are not objectionable, but only those which seriously block the movements of fish. Some act as barriers, preventing the scouring out of a stream during freshets, and as such are desirable.

The problem of maintenance of stream flow and prevention of devastating freshets on many streams calls for serious consideration. Fish culture of the future must turn more and more to the care of nature's great production areas—the streams and lakes. It is impossible at the present time to determine even approximately the number of sockeye salmon eggs deposited on the spawning beds in any one year. The number is undoubtedly vast. In 1929, the pack of sockeye in British Columbia was 281,277. To this should be added 111,898 cases packed in the state of Washington. The total pack therefore would be approximately 400,000 cases, representing in the neighborhood of 4,800,000 fish. If the relation of catch to escapement was 50:50, then 2,400,000 females passed to the spawning beds, and allowing 4500 eggs to a female there should have been deposited in 1929 about 10,800,000,000 eggs. This, no doubt, is a conservative estimate but the point desired to be emphasized is that the care of the streams with their spawning beds and eggs should receive primary consideration in any comprehensive program of fish culture.

Assistance to Propagation By Artificial Measures

In addition to that assistance given to propagation through the supervision and care of the water areas, some further assistance may be given by the use of so-called artificial measures. Hatcheries undoubtedly play a part in the general program of sockeye salmon conservation. Their main value would appear to be in the maintenance of a reserve supply of eggs in those areas subject to severe climatic conditions and in the provision of a supply of eggs or fry for transplantation to areas depleted through unusual adverse physical conditions or through overfishing. There are in the Province at the present time eight hatcheries which in 1929 handled approximately 85,000,000 eggs. A portion of the hatchery product was planted as eyed eggs in the gravel beds of various streams and the remainder distributed as fry in the lakes. The efficiency of artificial measures as compared with that of natural propagation has never been accurately determined. The Biological Board of Canada is attempting to obtain accurate data in this respect at Cultus lake on the basis of actual counts of seaward migrants from natural spawning, from the planting of eyed eggs and from the distribution of fry. Such information is obviously of fundamental importance.

While it has been established that sockeye tend to return to their parent streams, transplantation of eggs and fry to other areas has

apparently been attended with varying success. Accurate data are lacking here also, and the Biological Board is carrying out an experiment by transferring eggs from Cultus lake to Eagle river, a tributary of Shuswap lake, 300 miles north-east on the Fraser river system. The eggs were hatched in a temporary hatchery, the fry held in ponds for seven months until large enough to mark by the clipping off of fins and then were released in the river. Fences in Eagle river and in the outlet of Cultus lake will make possible the interception of any returning adults in 1932. In the year following the initiation of the above experiment, the work was extended by the collection of eggs from Adams river, also a tributary of Shuswap lake, with subsequent holding and marking of fry. The returns to Eagle river in the respective cycle years should give some indications as to the success of transplantations.

The question as to whether sockeye fry should be retained in ponds for some time before being liberated in the lakes has been raised. An attempt to secure an answer is being made at Cultus lake by the Biological Board with the co-operation of the Dominion Department of Fisheries. Fry are being held in specially constructed ponds. At the end of six months half the number of the young fish will be marked by removal of certain fins and then released in the lake. At the end of the year the remainder will be marked by removal of different fins and then released. The enumeration of seaward migrants at the counting fence in the outlet of the lake should provide data regarding the efficiency of retention in ponds for the above mentioned periods as compared with fry liberation.

If in succeeding years the efficiency of artificial propagation of sockeye salmon is thoroughly established, undoubtedly development will take place in the field of selective breeding. At least experiments should be conducted to determine the possibilities of selection of fish for size, age of maturity, season of return from the sea, and other characteristics.

Agencies Working Against Salmon Production

There are certain factors working against conservation. These are associated with the agricultural and industrial development of the province. Clearing of the land in agricultural and lumbering activities is resulting in more rapid run off of water from the watersheds with resultant severer freshet conditions and diminished flow during certain months of the year. Protection of headwaters and a policy of reforestation appear to be the solutions.

Furthermore, industrial development has brought two serious menaces, namely, pollution of both streams and coastal waters and dams across streams. The pouring into the water of substances injurious to the plants and animals is inexcusable. In this age of science there should not be a single problem of disposal of industrial waste incapable of being satisfactorily and economically solved.

The problem of dams is one of the most serious situations facing the fishing industry at the present time. Dams prevent the ascent of salmon upstream, interfere with the passage of the young downstream and in some cases cause the flooding of spawning beds. Electrical energy is desired but must it be at the expense of the destruction of a valuable natural food resource? It would seem that the time has arrived when a commission composed of all parties intimately interested should be formed to thoroughly consider the situation and make provision for an intensive study of the problem by a body of eminent engineers and fishery biologists.

Conclusion

In the foregoing an attempt has been made to outline in a general way the problem of the conservation of the sockeye salmon in the waters of British Columbia. It is hoped that the statements may serve to place the situation in a clear light and especially to indicate the objective to which all the regulatory, cultural and investigative endeavors are aimed.

THE EFFECT OF TEMPERATURE UPON THE INGESTION OF BACTERIA BY THE CLAM (MYA ARENARIA)

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Several investigators have established the fact that the oyster ceases active feeding when the temperature of the water falls below a critical point between 41° and 45° F. This state of hibernation has an important relation to the sanitary regulation of oyster beds in water polluted by sewage, since the ingestion of pathogenic bacteria is reduced to a minimum during the winter months. Conversely, the cleansing of the oyster by the chlorination process depends upon its "drinking" or feeding, and consequently the present methods of chemical purification are ineffectual in water below 45° F.

In 1930 commercial chlorination plants were established in Massachusetts for marketing clams from polluted areas. Since the operation of these plants will continue throughout the winter, it was most important to know whether or not the clam ceased feeding at the same temperature as the oyster. To answer this question a series of experiments, comprising direct observations upon the passing of water currents through the clam and quantitative bacteriological studies, were conducted. To establish the exchange of bacteria both in and out of the clam, *Bacillus prodigiosus*, a bacterium which is readily recognized by its red color and which is never present normally in clams, was used.

The experiments showed that the clam will feed normally between 35° F. and 39° F. and that bacteria are as readily ingested at 37° F. as at 80° F. The clam, a northern species, ceases feeding at a lower temperature than the oyster. Owing to the longer feeding period, unlike the oyster, clams from polluted waters are as dangerous during the greater part of the winter as during the summer.

Clams will cleanse themselves of bacteria as readily at 37° F. as at 80° F. Consequently, the commercial chlorination process, which is dependent upon the self cleansing of the clam, will be as effective during the winter as during the summer, without resorting to artificial heating of the water.

NOTES ON THE EXPOSURE OF YOUNG FISH TO VARYING CONCENTRATIONS OF ARSENIC

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Introduction

In 1926 Domogalla (1) published some results on the use of sodium arsenite to control aquatic vegetation. Surber (2) used sodium arsenite to control the growth of aquatic vegetation in certain sloughs on the Upper Mississippi River. Both of these investigators found that a concentration of from 1–2 p.p.m. of As_2O_3 would destroy the larger aquatic vegetation and would not have a deleterious effect on the fish life or on the plankton organisms. These results suggest arsenic as a means of controlling the growth of vegetation in fish ponds.

The present investigation was undertaken in an effort to determine definitely whether or not small fish can stand the concentrations of arsenic required to destroy vegetation. Ebeling (3) reports that he kept a rainbow trout for 48.5 hours in water containing 5 mg. As. per litre. This fish remained alive after it was put in pure water.

The fish used in these experiments were the largemouth black bass (micropterus salmoides), the smallmouth black bass (M. dolomieu), the white crappie (Pomoxis annularis), the bluegill (Lepomis incisor), the golden shiner (Notemigonus crysoleucas), the goldfish (Carassius auratus), and the bullhead (Ameiurus nebulosus). All fish were of fingerling sizes. (Unless specified otherwise, when the term bass is used in this paper it has reference to the largemouthed.)

The experiments were carried out in glass aquaria having a capacity of 200 litres. A control aquarium of the same size was operated to eliminate the error due to handling of the fish.

The pH of the water was determined before and after the addition of the arsenic. The change in pH due to the excess alkali of the arsenic solution amounted generally to 0.2 pH units. In two instances the change amounted to 0.35 and 0.50 pH units respectively. These changes in pH had apparently no ill effects on these fishes. Enough dissolved oxygen determinations were made to know whether or not the fishes were suffering from want of oxygen. Temperatures were also taken each time an aquarium was treated. The results on pH and dissolved oxygen determinations have no direct bearing on these experiments and they are therefore omitted from this paper.

The source of arsenic was either the C.P. arsenious oxides or the commercial sodium arsenite. The latter was obtained from the U. S. S. Lead Refinery Inc.

Experimental

A series of experiments was carried out in each of three aquaria. These were labeled A, B, and C. The experiments for the three aquaria are taken up in the order named.

Aquarium A

Experiment No. 1

On. Oct. 19th, 5 bass, 5 crappie, 5 bluegill, and 5 goldfish were placed in this aquarium. The control aquarium was stocked at the same time with the same number and kind of fishes.

On Nov. 1st, at 10:30 A.M., enough of the sodium arsenite solution was added to give the water an As_2O_3 content of 2 p.p.m. This experiment was terminated at 2 P.M. on Nov. 4th. No fishes were lost during this experiment. The control likewise lost no fishes.

The water was changed at the end of the experiment and the fish returned to the aquarium to be used again in experiment 2.

Experiment No. 2

On Nov. 5th, at 8:30 A.M., enough sodium arsenite solution was added to this aquarium to give the water an As_2O_3 content of 4 p.p.m. At 10 A.M. on Nov. 5th 1 bluegill was dead. At 12 noon another bluegill was dead. Nov. 6th, 8:00 A.M., 1 goldfish, 1 crappie and one bass were dead. The experiment was terminated at 2 P.M. on Nov. 11th with a loss of fishes as just indicated. Two bluegill in the control had died during this time.

The water was changed again and the 15 fishes that survived were used in the next experiment.

Experiment No. 3

At 10:15 A.M. on Nov. 12th enough sodium arsenite was added to the water in this aquarium to make a concentration of 6 p.p.m. of As_2O_3. This experiment was terminated at 1:00 P.M. Nov. 13th. No fishes were lost in either the experimental or the control aquarium. The water was changed and the same fishes used in experiment 4.

Experiment No. 4

This was a repetition of the preceding experiment and lasted from 9:00 A.M. Nov. 14th to 1:00 P.M. Nov. 16th. No fishes were lost. The control likewise lost no fish.

At the end of this experiment the fishes from aquarium A were transferred to a trough where they were supplied with untreated running water. These fishes were still alive and healthy on March 25th, 1930. Some of these fishes are still alive and healthy.

Experiment No. 5

Aquarium A was stocked with new fishes as follows: 5 bass, 5 crappie, 5 bluegill, 5 goldfish and 5 shiners. (The fishes in the control aquarium were not changed this time, but 3 bullheads were added to act as a control against the bullheads in aquarium C.)

On Nov. 19th, at 8:00 A.M., enough sodium arsenite was added to the water in aquarium A to make a concentration of 6 p.p.m. of

As_2O_3. This experiment was continued until 1:00 P.M. Nov. 25th. No fishes were lost in either the experimental or control aquarium.

This experiment differs from the preceding in that the fishes were exposed to 6 p.p.m. at once, whereas before they were exposed first to 2 p.p.m. then to 4 p.p.m. and finally to 6 p.p.m.

The water was changed at the end of this experiment, but the same fishes were used in experiment 6.

Experiment No. 6

On Nov. 26th, at 8:30 A.M., enough arsenic oxide solution was added to make a concentration of 4 p.p.m. of As_2O_3. The arsenic solution used was prepared by dissolving arsenious oxide in Na OH. On Nov. 27th, 1 shiner and 1 bluegill died.

This experiment was terminated at 1:00 P.M. of Dec. 2nd. The fishes lost in the treated aquarium were as just indicated. The control lost 1 bass, 1 bullhead, and 2 goldfish in the course of this experiment.

After this experiment the fishes from Aquarium A as well as those from the control aquarium were transferred to separate troughs and supplied with running water uncontaminated with arsenic. On Jan. 5th, 1930, only 1 bluegill of the treated lot of fishes had died in the trough whereas of the control fishes 5 crappie and 2 bass had died. After this date no record was kept of the control fishes, but the treated fishes are still (March 25, 1930) alive and healthy.

Experiment No. 7

This experiment was begun at 8:30 A.M. on Dec. 6th with the following new fishes in the Aquarium A: 5 bass, 5 goldfish, 10 bluegill, 2 crappie and 5 shiners. The control had the following fishes: 5 bass, 1 crappie, 10 bluegill, 5 shiners, 5 bullheads, and 5 goldfish.

The water in Aquarium A was again treated with enough of the alkaline solution of arsenious acid to make a concentration 4 p.p.m. of As_2O_3. This experiment was terminated at 9:00 A.M. on Dec. 13th. The treated aquarium had lost 3 bluegill and the control 3 bluegill and 1 bass. The surviving fish from both aquaria were discarded and fresh fishes used in the next experiment.

Experiment No. 8

For this experiment Aquarium A was stocked with 5 bass, 5 shiners, 10 bluegill, 1 crappie and 5 goldfish; the control with 5 bass, 5 shiners, 5 goldfish, 10 bluegill, and 5 bullheads. (The bullheads are the same fishes that were in the control during experiment 7.)

This experiment was begun at 9:45 A.M. on Dec. 21st. Again a concentration of 4 p.p.m. of As_2O_3 was used. The arsenic used was an acid solution of arsenious oxide. During this experiment, which was terminated at 1:00 P.M. on Dec. 28, the treated aquarium lost 1 bluegill and the control 1 goldfish. These fishes were transferred to

troughs of running water on Dec. 28th, 1929. The control fishes were mixed with other untreated fishes, but the treated fishes were kept in a separate trough. On March 25th, 1930, these were still alive and vigorous.

Experiment No. 9

For this experiment Aquarium A was stocked with 5 large mouth bass, 1 small mouth bass, 5 goldfish, 2 crappie, 5 shiners and 5 bluegill. The control was stocked with 5 bass, 5 bullheads, 5 goldfish, 5 shiners, 2 crappie, and 5 bluegill. All the fishes except the bullheads used in this experiment were new fishes.

At 8:30 A.M. on Dec. 31st, 1929, Aquarium A received enough sodium arsenite solution to make a concentration of 4 p.p.m. of As_2O_3. This experiment was terminated at 10:00 A.M. Jan. 7th, 1930. Of the treated fishes 2 bluegill and 1 bass had died and of the untreated 1 bluegill and 2 bass.

The experiments performed in Aquarium A are summarized in Table 1. The table shows that a total of 121 fishes were used; 14 or 11.57 per cent of these were lost during the course of these experiments. In the control aquarium 14 (13.86 per cent) fishes out of a total of 101 died.

Table 1 shows number of fish used, duration of each experiment, concentration of As_2O_3, number of fish lost, and temperature for Aquarium A.

TABLE 1

No. of experiment	No. of fishes used	Duration of experiment in hours	Conc. of As_2O_3 in p.p.m.	Temperature degree centigrade	No. of fishes lost in experimental aquarium	No. of fish lost in control
1	20*	75.5	2	20.0	0	0
2	20	149.5	4	16.5	5	2
3	15	26.75	6	17.0	0	0
4	15	52.0	6	16.0	0	0
5	25*	148.5	6	16.75	0	0
6	25	148.5	4	14.5	2	4
7	27*	168.5	4	17.0	3	4
8	26*	171.5	4	16.0	1	1
9	23*	169.5	4	17.0	3	3
Total	121					

* Indicates new fish.

Aquarium B

The series of experiments performed in this aquarium differ from those in Aquarium A only in the concentration of arsenic, and in the number of fishes used. It is, therefore, not necessary to describe these experiments in detail. The results are summarized in Table 2. The table shows that a total of 128 fishes were used. Only 10 or 7.81 per cent were lost. The control lost 14 fishes or 13.86 per cent during the same period. The concentration of As_2O_3 ranged from 2–7 p.p.m.

Table 2 shows number of fishes used, duration of experiment, concentration of As_2O_3, temperature and number of fishes lost for Aquarium B.

TABLE 2

No. of experiment	No. of fishes used	Duration of experiment in hours	Conc. of As_2O_3 in p.p.m.	Temperature degree centigrade	No. of fishes lost in experimental aquarium	No. of fish lost in the control
1	20*	75.5	2	20.5	0	0
2	20	149.5	5	16.5	3	2
3	17	26.75	7	17.0	0	0
4	17	52.0	7	16.0	0	0
5	25*	148.5	7	16.25	1	0
6	24	148.5	6	15.5	1	4
7	27*	168.5	6	17.0	1	4
8	26*	171.5	6	16.0	1	1
0	30*	169.5	6	17.0	3	3
Total	128					

*New fishes.

Aquarium C

Experiment No. 1

This experiment was begun at 8:30 A.M. on Nov. 26th with the following fishes in the aquarium: 8 golden shiners, 3 bluegill, 5 bullheads, and 10 goldfish. Enough sodium arsenite was added to give the water an arsenic content of 2 p.p.m. As_2O_3. This experiment lasted until 1:00 P.M. Dec. 2nd. No fishes were lost. The control lost 1 bullhead.

Experiment No. 2

On Dec. 2nd, the water in this aquarium was changed and the fishes used in experiment 1 returned to it. There were also added 7 more bluegill and 5 bass, so that in the second experiment this aquarium contained 8 shiners, 10 bluegill, 5 bullheads, 10 goldfish and 5 bass.

On Dec. 6th, at 8:30 A.M., this aquarium received enough of an alkaline solution of arsenious oxide to make a concentration of As_2O_3 of 2 p.p.m. This experiment was terminated at 9:00 A.M. on Dec. 17th with no loss of fishes. The control lost 1 bass and 3 bluegill.

The water was changed and the fishes used again in experiment 3.

Experiment No. 3

This was a repetition of No. 2 except that an acid solution of As_2O_3 was used instead of the alkaline solution. The experiment lasted from 9:00 A.M. Dec. 17th until 9:00 A.M. Dec. 24th. One bass was lost during this experiment. These fishes were again used in the next experiment.

Experiment No. 4

On Dec. 24th, without changing the water, enough sodium arsenite was added to make a concentration of 2 p.p.m. As_2O_3. The water in this aquarium had already received sufficient As_2O_3 on Dec. 17th to make a concentration of 2 p.p.m. The arsenite added now was in addition to that.

This experiment was terminated at 10:00 A.M. on Jan. 1st, 1930. The only fishes lost were 1 shiner and 1 bluegill. The control lost 1 bluegill.

Table 3 shows: number of fishes used, duration of each experiment concentration of As_2O_3, number of fishes lost, and the temperature for Aquarium C.

TABLE 3

No. of experiment	No. of fishes used	Duration of experiment in hours	Conc. of As_2O_3 in p.p.m.	Temperature degree centigrade	No. of fishes lost in experimental aquarium	No. of fishes lost in control
1	26	172.5	2	12.0	0	1
2	26 + 12*	168.5	2	16.0	0	4
3	38	168.0	2	16.0	1	Not in operation
4	37	169.0	2	9.0	2	1
Total	38		.		3	6

*New fishes.

Summary

Table 3 summarizes the important points in this series of experiments. This series differs from those in Aquaria A and B in that lower concentrations of arsenic were used and that the fishes were exposed to the arsenic for a longer period. Table 3 shows that a total of 38 fishes were used. Only 3 or 7.9 per cent of these were lost. The control lost 6 fishes during the same period. The total time that fishes were exposed to arsenic was 29 days. The total time taken by the experiment was 36 days.

Conclusion

As stated in the introduction these experiments were undertaken for the purpose of determining definitely if the amounts of As_2O_3 required to destroy aquatic vegetation would be harmful to the fishes inhabiting the water. The results seem to show that the fingerlings of our common warm water game fishes at least are not adversely affected by concentrations of As_2O_3 considerably in excess of those required for the destruction of vegetation. Exposure to concentrations of As_2O_3 as high as 7 p.p.m. for a shorter period from 26 hrs. to 148 hrs. do not seem to affect these fishes adversely. This is suggested by the fact that fishes that have been exposed thusly are alive and healthy 3 months afterwards. Considerably longer periods of exposure to 2 p.p.m. also seem to have no deleterious effect. The fishes that did die in the experimental aquarium were probably not killed by the arsenic. Any one that has ever handled any fishes knows that a certain number of fishes will die merely as the result of handling. Moreover, more fishes were lost in the control aquarium than in the aquaria that were treated in the arsenic.

No attempt has been made to determine the lethal dose.

Summary

(1) The fingerling stages of 5 species of game fishes and of 3 species of forage fishes have been exposed to concentrations of arsenic ranging from 2 p.p.m. to 7 p.p.m. for varying periods of time.

(2) These concentrations of arsenic did not have any harmful effect on these fishes.

(3) The concentrations of arsenic required to destroy aquatic vegetation are not injurious to fish life.

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Discussion

MR. CULLER: I would like to ask Dr. Wiebe if he has tried the arsenite compound in fish ponds or in any of the landlocked sloughs in the neighborhood of Fairport.

DR. WIEBE: Yes, we have treated a few ponds and killed the vegetation, and as far as we know we have not killed the fish.

MR. CULLER: In killing the vegetation it disintegrates and falls to the bottom, does it not?

DR. WIEBE: Yes.

MR. CULLER: Is there not carbon dioxide formed that is apt to have a deleterious effect on the fish life?

DR. WIEBE: The carbon dioxide is not formed rapidly enough to injure fish. Fishes can stand a very high concentration of carbon dioxide; even as much as fifty parts per million is harmless. In our ponds where the water is ordinarily alkaline, most of the time we have a carbon dioxide deficiency as high as 75 to 80 parts per million. So that it is not likely that in these waters decomposition would take place so rapidly that there would be enough carbon dioxide formed to be detrimental to fish life.

MR. CULLER: In our operations along the Mississippi river, we have a large number of lakes which are densey populated with vegetation. If these lakes were treated in the fall and we were unable to take the fish out when the ice formed, would there not result a loss of fish life?

DR. WIEBE: If you have sufficient decaying vegetation to consume all the available oxygen, it would be much more serious than the accumulation of carbon dioxide and the fish would die when shallow water freezes solidly for several months; the oxygen would be depleted and the fish would die in any case.

As a matter of fact, the arsenic is removed from the water rapidly. Dr. Domogalla and Dr. Peterson could find in a very short time no traces of arsenic in the water, except in the bottom mud. It precipitates out by combining with the iron hydroxide of the water.

MR. TITCOMB: Do you think that arsenic could be applied in a trout pond, for instance?

DR. WIEBE: Dr. Ebeling, a German worker, has exposed a trout to five parts per million, and the trout suffered no unfavorable consequences.

MR. TITCOMB: Will the vegetation return?

DR. WIEBE: It does not eradicate the vegetation for good. If you had to cut the vegetation several times during the summer it would be much more expensive than several sprayings.

MR. TITCOMB? How quickly is the vegetation cut down by the arsenic?

DR. WIEBE: It will sometimes disappear after two days.

MR. TITCOMB: Will it take the larger plants, such as Potomogeton?

DR. WIEBE: Yes, that is what it is used for especially—the large vegetation.

MR. TITCOMB: Would you have to use different proportions for hard and soft water?

DR. WIEBE: In soft water you probably would use less. Sodium arsenite will combine generally with those elements that make for hardness of water, so that soft water would require a lower concentration, because the arsenic would have a greater tendency to remain in solution for a longer time and therefore would be more effective.

MR. TITCOMB: Would it be proper to ask how this arsenic is applied in the lake or pond?

DR. WIEBE: Simply by the use of a sprayer, the same kind that you would use in spraying trees, i.e. a power sprayer, or hand sprayer, or even a sprinkling can. The most important point is to know as far as possible the volume of water you are treating.

MR. TITCOMB: What proportions do you use in the practical application?

MR. E. W. SURBER: One gallon of sodium arsenite for every 64,082 cubic feet of water.

MR. POWELL (Maryland): What effect does the arsenite have on insect life?

DR. WIEBE: That I have not investigated. Mr. Surber has done some work on that phase of it, and perhaps he could answer the question.

MR. E. W. SURBER: In general, one and one-half parts per million seems to have caused a reduction, though not a total destruction, of the aquatic insects. Naturally there would be a destruction of the aquatic insect larvae, because they are more dependent on the aquatic vegetation than on the plankton. If you kill a large proportion of the vegetation, you are bound to eliminate a large number of the aquatic organisms.

MR. POWELL: What effect would the application of arsenite have upon the crustacean life in the algae?

MR. E. W. SURBER: It should not have any material effect on Daphnia, because most of the Cladocera are dependent on single cell green algae as food.

MR. TITCOMB: But when you are buying the arsenite, in what form is it obtained?

MR. E. W. SURBER: You can buy the commercial product in five, ten or fifty-five gallon drums. If you buy it from the U. S. S. Lead Refining Company, it is a standard weed killer solution of definite strength. I can furnish an exact description of its chemical composition and the percentage of arsenious oxide in the weed killer, if anyone would like to obtain it.

DEPLETION OF THE AQUATIC RESOURCES OF THE UPPER MISSISSIPPI RIVER AND SUGGESTED REMEDIAL MEASURES

C. F. CULLER

U. S. Bureau of Fisheries

In this paper the writer is discussing certain problems affecting the Fisheries of the Upper Mississippi River. These problems are of vital importance to the general public because of the Federal Upper Mississippi Wild Life and Fish Refuge being included in this area and because of plans of the government to provide a nine-foot channel through this part of the river, thereby changing the river in a sense into a series of pools behind dams in the interests of navigation.

The three major problems affecting aquatic life within the boundaries of the Upper Mississippi River Wild Life and Fish Refuge may be summarized under three general headings: 1. Pollution. 2. Erosion. 3. Fluctuation of water levels. All three of these problems are man-made and are the result of the activities of civilization in the Mississippi River watershed. These are increasing in their destructiveness to aquatic life with the increase in industry and population. With the stimulation given fishing by two fisherman presidents and the rapidly spreading interest in the out-of-doors which has resulted in ten fishermen today compared with one fisherman ten years ago, these three major causes of depleting aquatic life along the Upper Mississippi River become problems of general concern.

The time is not far distant when the Bureau of Fisheries and the Conservation Departments of the various states bordering this vast Mid-west playground will have to establish a program of co-operation for the restocking of the river. It is a conservative estimate to say that on any fair Sunday during the fishing season, the Refuge area will average a hundred fishermen to the mile. The Refuge is 283 miles long, which means that 28,300 people out of the five million population within easy motoring distance of the Refuge go fishing each Sunday. If each one of them of an average catches four fish, these figures would indicate that 113,200 fishes find their way each Sunday from the river to the frying pan.

This vast quantity of fishes has an economical value that probably affects the Monday income of every butcher within the Refuge territory. But this economic return is only incidental when one considers the recreation and sport these fishermen and fisherwomen enjoy. In addition to this, we must consider the mental rest that comes when one fishes, and the new ideas that are born between bites. Some day some fisherman is going to hit on the solution to the farm problem while waiting for a bass or pickerel to grab his lure.

Considering the recreational and commercial value of fishing to the growing population the Refuge serves, it is of the utmost importance that an adequate supply of fishes is maintained in the Upper Missis-

sippi River. The present source of supply comes only from natural hatching, there still being sufficient spawning grounds left, despite the closing of valuable bayous and sloughs by the wing dam construction of the War Department, to more than supply ample fish for anglers and the commercial fishing industry of the river if the three mentioned destructive elements could be eliminated or curtailed.

Pollution is the most destructive of the menaces mentioned. A large amount of acids, oils, dyes, tannins and other commercial wastes, and some organic sewerage originating in the Twin Cities, as well as in all other communities along the river, is constantly pouring into the Mississippi River. There is not at present a single sewerage disposal plant along the entire Upper Mississippi to care for these wastes and this pollution has reduced the oxygen content of the water above Lake Pepin to such an extent that it no longer supports fish life. Conditions in Lake Pepin, which 40 years ago was one of the finest bodies of fresh water in the Middle West, and abounded with fish life, are nearly as bad. During the winter of 1929–30 the oxygen content of this lake was so low that all fish life was seriously affected and it is possible that only a timely thaw saved the countless numbers of fish, wintering in the deep waters of the lake, from complete destruction.

Pollution has extended below Lake Pepin in such quantities that it is no longer economical to continue artificial propagation of mussels, and the Bureau of Fisheries has this year discontinued this work in these waters. Most of the valuable Upper Mississippi clam beds have been destroyed by the effect of pollution and erosion. Closed season protection was tried for a number of years but was found inadequate as protection alone could not build up clam beds and areas destroyed by these agencies. The vanishing of the clam from the river is the commencement of the end of the valuable button industry in this section unless other methods of propagation are developed commercially. There is hope that the menace of pollution to fresh water mussels will not obliterate mussel culture, as mussel propagation in the river is to be substituted by a new method of artificial propagation, and the rearing of larval mussels in clean waters elsewhere is to be pursued.

Due to the efforts of Mr. Judson L. Wicks, President, state division of the Izaak Walton League of Minnesota, a campaign was launched five years ago to eliminate from the river the pollution created by the Twin Cities. Through Mr. Wicks' efforts a legislative committee created a sanitary commission, which has functioned for three years and expended upwards of $100,000 in the study of the problem as it affects the Upper river. In all probability a sewerage disposal plant capable of caring for the sewerage from these two cities will be established within another year as a result of the committee's findings.

The War Department in its plan to construct a nine foot channel undertakes another project favorable to the battle against pollution

along the river. The dams planned will retard the water and the pollution will remain near its source. Thus the cities giving out the greatest amount of sewerage will have the greatest amount of sewerage under their own noses and it will no longer be a matter of fish life, but a problem of public health, which the public will insist be taken care of. This is an established fact, because at the river beaches at Winona, LaCrosse and other points along the river, bathers have suffered eye, ear and skin troubles which doctors traced directly to the unhealthy, polluted condition of the water.

The second important problem is erosion. Forestry engineers report that 25,000,000 cubic yards of sand and silt are washed into the Mississippi River annually between the mouth of the Chippewa and the mouth of the Wisconsin Rivers. If this silt were deposited in one place, it would raise the bottom of the river three feet for a distance of 10 miles and a width of two-fifths of a mile. It can be readily understood the effect this drifting sand and silt has on spawning beds along the river and on the bottoms of the numerous lakes and sloughs within this area. Even in the backwaters during spring freshets the water is muddy and unsuitable for spawning; it buries eggs, separates young fish from the main body of water, and has reduced the spawning beds of the smallmouth bass along the river channel to such an extent that this gamiest of river fishes is required to migrate to favorable waters. Silt, with the vast volume of organic matter disposed in the river, is an immense factor in the depletion of fish life. This drifting material has also buried many of our best mussel beds. In some places it mixes with the polluted matter and forms a muddy mire in the river bottom which tests have revealed to be eight to ten feet deep. Dr. M. M. Ellis in his scientific experiments at Keokuk dam found such conditions very unfavorable to fish life. By reducing the hatch of fish each year, this silt has materially affected the food supply, and in some sections it has materially changed the aquatic plant and animal life of the river. Its effect on food fishes is probably as great as on game fishes. Commercial fishing of carp and buffalo has been reduced by the effect of erosion more than by the commercial fishing on the Upper river. In fact, it is rapidly reducing the commercial fish resources of the river, and if conditions continue, commercial fishing on the Mississippi River is doomed to destruction as were the fresh-water mussel fisheries.

The proposed "nine foot" channel project for the Upper river, now before Congress, under which the water will be slackened by a series of dams and the river changed into a series of slack water pools may benefit erosion conditions, as the slackened water will not carry as great a quantity of silt as before, but will deposit it at the head of each pool. Whether this will produce a clear water condition between the dam and the head of the pool is a matter of uncertainty. If it does not, a condition similar to that now existing in Lake Cooper above the Keokuk dam will exist. The dams may also clear the water in the

sloughs by depositing the silt load before it reaches the backwaters from feeder creeks and rivers. This would aid in increasing and restoring the spawning bed areas in the flooded backwaters. The backwaters from the dams, however, will cover many valuable spawning beds and feedings areas to a water depth unfavorable to fish propagation.

The third serious problem confronting fish culture on the Upper Mississippi is the varying stage of water. The water variation in the river averages as much as 12 feet during the year, and there is no certainty as to time of fluctuations, although there is an annual rise in the spring which permits various species of shallow water spawning fishes to enter the backwaters. Millions of fishes are hatched in these backwaters of the Mississippi each spring.

In June, July or early August there is a decisive drop in the river. The stage this year is below zero, the lowest it has been in forty years. The falling river landlocks in the backwater sloughs, lakes, and pools millions of young fishes as well as many adults, but most of the adults and some small fish of certain species react to the falling water and escape to live waters.

Nature has no way of preventing all these landlocked fishes from perishing. In summer, evaporation and seepage bring about the complete drying up of innumerable backwater pools and lakes, leaving the fish to perish, and in winter the oxygen content of the water decreases beyond a point that will support fish life, a condition caused mainly by pollution and low water.

The Bureau of Fisheries to prevent this immense loss of fish has for the past thirteen years been conducting extensive rescue work. At the present time there are 16 crews composed of 102 men engaged in rescue activities within the boundaries of the Refuge. Fishes are removed from waters completely landlocked only where there is no possible chance of their survival.

In 1929 these crews rescued 155,477,522 fishes from such pools, replacing in the Mississippi 154,986,602, and shipping 490,920 to inland lakes for stocking purposes.

The fishes rescued were as follows: Black bass, 273,344; Crappie, 18,539,345; Sunfish, 25,726,203; Catfish, 85,091,108; Yellow perch, 2,644,112; Pike-pickerel, 445, 099; Carp, 3,694,096; Buffalo, 1,346,625; Drum, 1,985; White Bass, 281,250; Miscellaneous, 17,412,168; Bream, 22,035; Rock Bass, 150.

These figures give some idea of the immensity of this fish-saving work. It is safe to say that less than one-fourth of the total fishes spawned in these landlocked pools are saved. The balance die before the crews reach them or are consumed by predacious birds or by other natural enemies or die from lack of oxygen. The writer has counted as many as 25 blue heron around a pool, feasting on young bass. One blue heron recently killed had 102 fishes in its stomach. This is an example of the heron menace.

After the rescued fishes are placed in the river, they are subjected to natural enemies of which the garfish is the most destructive. Large schools of gar, which abound in the river, take great quantities of fingerling size fishes. As yet no satisfactory means has been found to destroy this killer, which probably consumes more fishes each year than all the 100 fishermen per mile catch along the river. Garfish today are a greater problem than any other destructive fish in the Upper Mississippi River. Carp are valuable food fish worthy of being retained in limited numbers in large bodies of water, but garfish as food are useless. It would be advisable to destroy them, under warden supervision, if funds could be obtained for the purpose. This would require special legislation.

What effect the proposed nine-foot channel will have on stabilizing the stage of water in the river is not yet definitely known. If fixed dams are used, the fluctuation probably will be less, and the number of landlocked pools will be reduced. The spreading of the water over large areas of bottomlands and the cutting of trees and the presence of brush and debris in the backwaters will bring about changes of questionable value. The Bureau of Fisheries has planned to provide other means of procuring warm water fishes for stocking inland lakes. A number of experiments are now in progress, using ponds located near or in the Refuge for artificial propagation. It is hoped to raise several million bass in this manner within the next few years. This plan will eliminate the necessity of collecting rescued fishes from inland waters for distribution. These propagated fishes may in time be used to stock the river proper should conditions require an adequate supply from lowland waters becoming a thing of the past.

We know that the nation has a broader view of Upper Mississippi conservation problems today than ever before. The Senatorial Conservation Committee composed of Senators Frederic Walcott, Harry B. Hawes, Key Pittman, and others spent a week in July investigating problems concerning the natural resources of this area, and we believe that in the new conservation program of the Federal Government there will be far-reaching policies that will eventually solve these three great problems, Pollution, Erosion, and Water Stage Variation. All are closely interlocked. When solved, the coming generation of fishermen will enjoy in the Upper Mississippi a fishing paradise, and a scenic playground surpassing most of the other wild life refuges in the country.

PRESENT AND FUTURE WASTAGE OF OIL AND WATER: EFFECTS AND REMEDIES

Dr. George W. Field

According to the topic which has been assigned to me on the program, I shall limit myself to the necessity of controlling oil pollution. Biologically, the answer to sewage pollution is to turn the waste material as quickly as possible into plant and animal life. Unfortunately pollution through mineral oils interferes to a great degree with this cycle and unless something is done speedily, the condition in civilized regions will be similar to that indicated by an epitaph I once saw on a tombstone: "Here lies the Body of James McPhail who Mistook a Rattler for an Eel." In this particular case the rattler is oil pollution; the eel is organized business and politics. We have to handle the eel of politics and of big business in such a way as to prevent it from doing the work of a rattler.

In order to handle the problem, a program looking toward the elimination and regulation of oil pollution was organized in 1923. It included two distinct aspects based upon jurisdictional aspects and political considerations. The first aspect called for an international conference, and a preliminary meeting was held in 1926. The next aspect was federal control of those areas which could properly be considered under the jurisdiction of the United States. It was found upon examination that the only phases of the problem which the federal laws could reach were the effect of oil on navigation and the navigability of the polluted waters. It was shown in 1924 that oil was interfering with navigation, and the result was the Oil Pollution Act of 1924. But the measure was not enacted in the form originally presented. As drawn by both the Senate and the House, it regulated the pollution by mineral oils of all the navigable waters of the United States. Organized interests, however, secured a compromise by which, instead of the wide extension originally proposed, its scope was limited to the discharge of oil in navigable coastal waters from vessels and not from refineries and plants located on the land. Nevertheless, a provision was inserted which called for the report of the army engineers with reference to the advisability of extending the law to the inland waters of the United States. The favorable report of the army engineers was held in abeyance for five years. Last year a bill was introduced extending these provisions to all the waters over which the United States had jurisdiction, including the waters of the Great Lakes and the navigable rivers and their tributaries. It is now being opposed by the oil interests, but we have every reason to believe that there will be no difficulty in having the bill passed as an amendment to the Oil Pollution Act of 1924.

Within the last week I attended a hearing with reference to the possibility of preventing the pollution of the waters of Boston harbor by oil. A police official said that, unless he had a force of men

sufficient to board all the vessels as they came in, oil pollution could not be prevented. The enforcement of the law is certainly inadequate. A perusal of the records of the army engineers who enforce this law show that only five convictions have been made in the past six years. Public sentiment does not realize the destructive effects of oil upon all forms of fish life.

One of the most important factors in connection with the control of pollution is that in certain regions of the United States, particularly in the Mississippi valley, there is during several months of the year insufficient water to take care of the pollutants.

At the present time the upper Mississippi valley is subject to a very severe drought. This situation can only be met by the construction of reservoirs of various sizes on the headwaters of all tributary streams for the purpose of controlling the runoff at its source.

The first project is to develop farm reservoirs by means of check-dams, which any farm can make at little expense, and turn the water into the ground. Further down there will be state reservoirs, and at the bases of all these tributaries large reservoirs which will hold a considerable amount of water. The problem is to take care of, at the minimum, 26,000,000 acre feet before it gets into the lower Mississippi regions. Those reservoirs must be distributed on all the five tributaries in such a way that the runoff of any one of these rivers can be controlled. Another means of preventing the water from going into this region where it is not wanted is the diversion of the tributaries of the Arkansas and of the Red rivers in such a way as to form large retarding reservoirs which can be turned into the arid region of Texas, for example.

The practical aspects of this move would be the possibility of increasing the amount of water needed to take care of the pollution. In this way the material could be converted into vegetation and the vegetation into fish and birds, thus making living conditions far better all over the entire region of the upper Mississippi.

POLLUTION OF THE UPPER MISSISSIPPI RIVER

Judson L. Wicks

President of the Minnesota Division of The Izaak Walton League of America

The River Above Minneapolis

Drainage Area. The Mississippi River, fondly known among Americans as the Father of Waters, begins its long journey of 2,477 miles to the sea in the Itasca Lake region of northern Minnesota. From its source, 1,475 feet above sea level, to Minneapolis, a distance of some 537 miles, it traverses a drainage area of 19,670 square miles, mostly level country, the northern portion largely wooded and dotted with lakes, the southern a fairly well settled farming country. This area has a considerable industry; a sewered population of about 125,000; and 26 treatment plants all but four of which give primary treatment only. Its total sewage discharge is estimated as equivalent to the domestic sewage of 150,000 people. The Mississippi enters the city of Minneapolis at an elevation of 802 feet, having lost some 673 feet of altitude in its journey of 537 miles from its source. It is now a stream of relatively clean clear water, slightly tinged with reddish brown, a little over 100 yards in width but of a very variable volume.

Discharge. Records of twenty-eight years show a minimum monthly average flow of 861 cubic feet per second (January, 1925) and a maximum of 32,758 (June, 1908). The flow is regulated somewhat by the operation of large government reservoirs, with a capacity of 93,792,000,000 cubic feet, near the river's source.

Water Fairly Clean. The river water, after filtration and chlorination, is used as a source of domestic water supply for both Minneapolis and St. Paul. It carried usually an oxygen content approaching saturation. In the river at this point are found pretty much all species of native fish and in fair abundance, considering the large toll taken by angling.

Recuperative Power of Stream. The comparative purity of its waters, though, as above noted, they have received the equivalent of the domestic sewage of 150,000 people, is impressive evidence of the recuperative power of streams. The great Father of Waters enters the metropolitan area of Minneapolis and St. Paul fairly pure, but, like many a country youth, contaminated by city life, he leaves it unspeakably vile. Here for the first time he encounters the befouling influence of large, modern sewer systems. Some sewers are of very ancient date, notably the *cloaca maxima*, built prior to the days of Caesar to drain the Roman Forum, functioning ever since and still going strong. But extensive sewer systems, as we know them, are of quite recent origin and they form the greatest enemy of the natural

stream. They are a human device for the rapid removal of liquid waste. Without them, such waste finds its way to the stream only by means of surface drainage and percolation, the first of which is more or less infrequent and the latter of which is slow. Of streams as large as the Mississippi it is probably true that were it not for sewers, they would flow fairly clean even through large centers of population. The patient river, friend of man, serves him in many capacities, even in that of scavenger, and only fails in that capacity when overloaded by the unnatural device of the sewer.

The River in the Twin Cities

Population. Minneapolis and St. Paul adjoin each other and are often called the Twin Cities. The former has a population (1930 census) of 462,611, and the latter, 270,883, making a total of 733,494—close to three-quarters of a million. It has been reckoned that a circle of twenty-five miles radius centered at a point between the two cities would enclose one million people. There are numerous industries in this area.

The Minneapolis Pool. Within the city of Minneapolis the river drops about 70 feet at the Falls of St. Anthony. Here is to be noted a very marked change in topography. Above these falls the course of the river has been almost exclusively through glacial drift. Below them and until after the south line of Minnesota is passed, about 175 miles distant, it flows in an old rocky valley excavated in pre-glacial times. Through the remainder of its course in the Twin Cities it flows between very picturesque, high, wooded banks, first past the grounds and stately buildings of the University of Minnesota and then for a stretch of about four miles to what is known locally as the High Dam, where it drops another 33 feet. This dam serves to create a pool some four or five miles long, the steep wooded sides of which have been acquired by the two cities for park purposes, and along their summits have been constructed scenic highways. The pool, thus bordered on either side for its entire length by a natural amphitheater of wooded banks, would, were it not for the impurity of its waters, serve as possibly the most picturesque rowing course in the world. It was with infinite regret that the University was obliged to abandon such contemplated use on the advice of the most competent sanitary experts. Into this pool there is discharged daily 65 million gallons of sewage. It receives the flow of all the sewers of Minneapolis save one, and of 13 St. Paul sewers. Since the completion of the dam in 1914 there has accumulated in the bottom of the pool a deposit of over 81 million cubic feet of sludge and silt, as against its total estimated capacity of 340 million cubic feet. In places the deposit is more than 12 feet deep and is increasing at the rate of 3 inches generally over the entire bottom, each year. In warm weather gas bubbles arising from decomposing organic matter produce a very

noticeable effervescence and large areas of the surface are covered at times with a thin scum or sleek, and offensive odors are given off. The sanitary survey made in 1926, hereinafter mentioned, revealed that during a large part of the summer of that year septic conditions prevailed with practically no dissolved oxygen at the High Dam; that the bacterial count of 2,500 per cubic centimeter at Camden Bridge (near the northern limits of Minneapolis) was increased to 750,000 at the dam—the B. Coli increase being from 3 to 1,650.

In St. Paul and the Packing Area. For the remainder of its course through the metropolitan area the river bed has a slope of about six inches to the mile, which would induce a relatively rapid current tending to prevent deposits, but the beneficial effect of this slope has been neutralized by the recent construction of another dam at Hastings, to be mentioned later. About three miles below the High Dam we come to the mouth of the Minnesota River, the added dilution of which, it would seem, should ameliorate conditions materially, but such is not the case. It is a sluggish stream in its lower reaches and its drainage area of 16,400 square miles has, largely, a comparatively low rainfall. Its discharge, when most needed, in drouth and under ice conditions, is the smallest. In flowing through St. Paul the river receives the discharge of that city's remaining 23 sewers and comes to the industrial area of South St. Paul and Newport already overcharged with pollution. This area is the seat of a large meat packing industry the annual kill of which, from the point of view of pollution load, is the equivalent of four million hogs. The effluent of the packing plants is of the character usual to the industry, except that it contains the so-called "paunch manure," which in some other localities is utilized as fertilizer.

The Pollution Load Complete. The sewage contribution of the metropolitan area is now complete. Mark you! All of this has been discharged raw into the river, without any treatment whatever! Between 1,100 and 1,200 miles of sewers furnish a maximum average dry weather flow of 144 million gallons per day or 223 cubic feet per second, a minimum of 74,020,000 gallons or 114 second feet. At a time of maximum sewage flow and minimum stream flow we have one gallon of sewage for 5.8 gallons of water. This is, concededly, a most unusual condition for this locality, but it has been reckoned that in order to avoid septic conditions in the Minneapolis pool a stream flow during the summer season of 6,000 second feet is required. Over a period of 28 years there has been less than that flow in that season, 49 per cent of the time. The sewage load is increasing each year about three million gallons per day or nearly 1.2 per cent annually. Due to its large proportion of industrial waste, chiefly contributed by the packing industry, it has been estimated that this total pollution load is the equivalent of the domestic sewage of 1,300,000 people.

As to the relative contributions of the communities toward this

sewage load, it may be said that those of Minneapolis and St. Paul are roughly the same in proportion to their populations but that of South St. Paul and Newport, with one and four tenths per cent of the actual population of the area, supplies 24 per cent of the entire load. The population unit in Minneapolis and St. Paul each contributes a domestic equivalent of about 1.35, that of South St. Paul and Newport 30, or 22 times as much. In other words, if the three communities may be likened to three naughty children playing in the mud, the Minneapolis boy is a very dirty boy, the St. Paul boy is just as dirty according to his size, but the South St. Paul and Newport boy has twenty-two times as much dirt on every square inch of his epidermis as either of his playmates.

Below the Twin Cities

The Hastings Dam. Just above Hastings there has been completed by the U. S. Government a dam which will serve to back the water up as far as the High Dam in Minneapolis, some thirty miles. This will doubtless have a very important influence on pollution conditions. The report of the survey made by the U. S. Public Health Service shows that for much of the time in the months of July and August, 1926, there was practically no free oxygen in the river from the High Dam to Hastings. It is true that the river flow at that time was unusually low, but certain data obtained in the summer of 1929, when the flow was about double that of the summer of 1926, show the oxygen resources of the stream to be about as low as they were in the former year. In that year, with a fairly rapid current, unimpeded by dams, some eight inches of sludge was found on the river bottom at Hastings.

From the confluence of the St. Croix River about three miles below Hastings to the Iowa line, some 137 miles, the river forms a boundary between the states of Minnesota and Wisconsin, and this accounts for the interest of the latter state in the river's polluted condition, referred to later. Due to a large influx of pure water from the St. Croix, the Mississippi at Red Wing, about twenty miles below, has effected a very considerable recovery. In point of dissolved oxygen, the 1926 survey showed that when the content was 6 p.p.m. at Camden Bridge, and 0 at the High Dam, it was about 2 p.p.m. at Red Wing, a point at which, it is said, fish can barely live.

Lake Pepin. And now we come to one of the most important factors in the Upper Mississippi pollution situation—Lake Pepin. Not far below Red Wing, about 45 miles below St. Paul, the river widens into a lake, roughly, from two to three miles wide and 22 miles long. Near its foot enters from Wisconsin the Chippewa River with a drainage area of 9,480 square miles. The Chippewa, from geologic ages, has brought down large quantities of silt and deposited them off its mouth in the valley of the Mississippi and has thus formed a

barrage constricting it to something like normal width and creating a vast reservoir now known as Lake Pepin, whose influence on pollution conditions is very marked. In the first place the stream flow is retarded. During the low water winter season, the theoretical period of detention in the lake is between two and three months. In summer, of course, it is not so long. The exposure in the open season of so large a surface to atmospheric action is an ideal means of replenishing oxygen supply. The lake thus serves as a huge settling and oxidizing basin. So the river, leaving the lake, is as rich in oxygen as it was at Camden Bridge in Minneapolis.

It may be well at this point to call attention to the seasonal condition of ice coverage, very serious from the point of view of the stream's oxygen supply. Ice cuts off the supply of oxygen which water normally obtains by contact with the air. This condition in our northern country would not be serious were it not for pollutional conditions that man has created. The economy of nature is wonderful and the research worker, poorly paid though he may be, is to be envied because of the thrills that he must from time to time receive in the study of that economy and the discovery of some of nature's secrets. Nowhere, possibly, is the providence of nature more wonderful than in the matter of the supply of free oxygen to water.

Free, or dissolved, oxygen is as essential to the existence of fish and other aquatic life as air is essential to the existence of man. It is fully as essential as food. And when the supply of any essential of life is cut off or diminished by seasonal change, it would seem to be wise to provide for such change. This is precisely what nature has done. The squirrel, as we all know, lays by its store of nuts for winter, the bee its honey, and it is said that the bear takes on an increment of fat to draw on during its hibernation. Nature seems to have had an equal solicitude, and to have made like provision, for the requirements of aquatic life.

The capacity of water for free oxygen is well known to be dependent upon its temperature. Cold water can absorb more than warm water. The capacity thus varies from about eight to fourteen parts per million. In the summer, when the water is warm, and all the agencies of oxygen supply, such as atmospheric action and plant life are active, the capacity is low, for the store of oxygen may be speedily replenished. Not so in the winter. And here is revealed the marvelous providence of nature. Before the formation of ice, during the long chilly weeks of late autumn, with their high winds inducing wave action, the temperature of the water has been reduced, its capacity for oxygen correspondingly increased, and it has been stored, often to the full measure of that increased capacity, with this life-sustaining element. But that is not all. Most waters contain, even in a state of nature, more or less pollution in the form of decomposing organic matter and this sets up a competition with fish life for the oxygen supply. The low temperature prevailing under ice coverage checks

this competition, and not only that, fish life itself has a lower demand due to its comparative inactivity. Such is the admirable provision of nature for the condition of ice coverage.

But now man enters the scene as a master mar-plot. With pollution he frustrates the beneficent scheme of nature. Nature has made wise and ample provision for the aquatic life that it has planted in its waters and has given it an ample store of oxygen to carry it through its season of stress, but man injects into those waters a vast mass of putrescent, rotting matter that steals away from it the store provided by nature. This is not conjecture. Studies made by the U. S. Public Health Service, the Minnesota Department of Health, and the Metropolitan Drainage Commission, later referred to, show that, year by year, with a fair degree of uniformity, the oxygen content at the foot of Lake Pepin is around 6 p.p.m. in summer, builds up to 11 to 14 in early December, drops to nearly 2 in February, a condition critical for fish life, and again builds up during the succeeding spring to about 6. The evidence is conclusive. Man has stolen from the squirrel his store of nuts!

The Wild Life Refuge. At Wabasha, near the foot of Lake Pepin, we enter the upper limits of an area of peculiar interest to fishermen, hunters, and all lovers of nature and wild life. Some eight years ago the Izaak Walton League, under the presidency of that great crusader, Will H. Dilg, led a movement that resulted in an act of Congress involving an ultimate appropriation of one and one half million dollars and setting aside for all time as a sanctuary for wild life and fish all the low lying shores and islands of the Mississippi from Wabasha, Minnesota, to Rock Island, Illinois, a stretch of some 265 miles. The major portion of this area has already been acquired and is being administered by the government Bureau of Biological Survey. This is, probably, the most extensive and important wild life sanctuary ever established by the hand of man. It constitutes a significant factor in the pollution problem, for its welfare is menaced by the growing pollution of its waters. The large investment of the government is imperilled. The Izaak Walton League looks upon this area as its child and its injury by avoidable pollution outrages the feelings of its members as well as those of the growing host of conservationists over the entire nation. There is something shocking and scandalous in the thought that this area and the upper reaches of the river below the Twin Cities should be obliged to abdicate their high rôle of ministering, by their noble beauty and grandeur, to the higher wants of man, and to assume the menial roll of scavenger to rid him of liquid wastes. For it is in this region that the river attains its highest scenic value and becomes comparable with the Hudson and the Rhine and, like them, is also invested with a wealth of myth, legend, romance, tradition and history.

Nine Foot Channel. Another factor in the pollution problem is presented by the recent act of Congress authorizing a nine foot channel

in the river. For the nine foot channel involves canalization of the river by a series of dams, and dams imply a succession of pools, such as those above mentioned, and a retarded flow. This may serve to very seriously aggravate the situation unless remedial measures are taken.

Diminished Fish Life. What about the effect of the pollution on fish and other aquatic life? It has already been noted that fish life in the zone from St. Anthony Falls to the St. Croix is, at most times, practically extinct. The zone below the St. Croix to the Iowa line, twenty years ago, was probably the most famous small-mouth bass fishing ground in America. (Incidentally, to the writer's mind, fly-fishing for small mouth is the very acme of the art of angling.) The big-mouth and the pike perch were also very abundant. Today there is practically no game fishing as far south as Wabasha and below there it is very poor compared with former years. In 1922, according to an economic survey made in 1928 by Prof. Roland S. Vaile of the University of Minnesota, the catch of commercial fish from the Twin Cities to Winona was 4,250,000 lbs. This has since fallen off about 75 per cent and not only that but the proportion of the undesirable carp has greatly increased. From this survey it would also appear that the clamming industry, once very important, has of recent years suffered a very serious decline. These effects are, of course, not due solely to pollution, but pollution has been an important factor.

What Is To Be Done About It? Such is the picture of the river as far south as the Iowa line. It is hoped that there has been gathered a fair conception of what the stream was as the good Lord gave it to us, and the treatment that it has received at the hand of man. What has been done about it? What is to be done about it?

This meeting is probably not interested in a detailed history of the movement for the purification of the river, which movement has now been under way for more than five years. Suffice it to say that due to a public demand, in no small measure stimulated by the Izaak Walton League, the legislatures of Minnesota and Wisconsin, in 1925, provided for a joint legislative committee composed of Senator Walter H. Hunt and Assemblymen Chas. B. Perry and Theodore Swanson of Wisconsin, and Senator James A. Carley and Representatives Otto Kolshorn and Joseph H. Masek of Minnesota. Senator Hunt is chairman of the committee. This committee made arrangements for a technical, sanitary survey of the river, which was made under the direction of Mr. H. R. Crohurst of the U. S. Public Health Service in 1926 and 1927, and on the strength of the report of this survey the Minnesota legislature of 1927 provided for the creation of a commission known as the Metropolitan Drainage Commission and charged it with the duty of making all the requisite preliminary studies and plans for a system of sewage disposal for the Twin City

area. That commission is composed of—Mr. Chas. F. Keyes, chairman, and Mr. Russell H. Bennett, both of Minneapolis; Mr. Oscar Claussen, vice-chairman, and Mr. J. W. Kelsey, both of St. Paul; and Mr. C. D. Tearse, of Winona. Its secretary and chief engineer is Mr. J. A. Childs of St. Paul. The community and the state at large are to be congratulated on the personnel of this commission and its staff, who made an exhaustive study of the whole subject, in which they have received the very valuable assistance and co-operation of the Division of Sanitation of the Minnesota State Board of Health under its able director, Mr. H. A. Whittaker. The commission, in a report* to the 1929 legislature, presented plans of various systems of disposal, one of which, probably the most approved and the one recommended by it, looks to taking all the sewage of both cities and South St. Paul and Newport to Pig's Eye, a low marshy area just below St. Paul, and the erection there of a treatment plant. Sedimentation only will probably meet requirements up to 1940 and from then onward to 1970 varying degrees of further treatment will be necessary. The construction of the intercepting sewers and settling basins is to be completed by 1940. Of much interest is the determination of the commission as to the requirements in the interest of fish life. The construction of the proposed sewer system would at once free the river from all sewer discharges between Camden Bridge and Pig's Eye, and so in that stretch it would seem that fish may be as abundant as above the cities.

There Will Be No Fish Life in the Hastings Pool. But without rather complete secondary treatment, fish life in the zone from Pig's Eye to the Hastings Dam cannot be maintained at all times. Beyond the nearby confluence of the St. Croix, even with only sedimentation at Pig's Eye and a moderate amount of secondary treatment, conditions, it is estimated, would be fairly tolerable for aquatic life. Full treatment, of course, involves a very great expense—the total cost of the proposed system (Project 1-5 with activated sludge treatment by 1940 for Minneapolis and St. Paul, exclusive of South St. Paul and Newport) being estimated at about eighteen million dollars. Sufficient of the system to prevent a nuisance by 1940, with activated sludge treatment at Pig's Eye, would cost around $13,500,000. Considering all the circumstances, the query arose—might it not be advisable to disregard the requirements of fish life in that short section of the stream provided a congenial habitat for it should be maintained below the St. Croix? After conference with the Minnesota Department of Game and Fish, that question has been answered in the affirmative. The measure of tolerated pollution in this instance is comparatively small and seemed justified by what were believed to be controlling economic considerations and is in line with a practice

*This report, a bound octavo volume of 403 pages, is a veritable mine of information from which the writer has taken much of the material for this paper.

more or less prevalent elsewhere of classification of public waters, placing in one class those which are to be maintained in their pristine purity, in another those in which pollution is permitted, but controlled, and in another those which, from all points of view except that of public health, are to be abandoned to pollution.

It may here be of interest to note the attitude of England upon this subject for nowhere, possibly, is the problem of pollution more acute than in that country. While there recently, the writer had the privilege of meeting and conferring with such of her sanitarians of international repute as Dr. H. T. Calvert, of the Ministry of Health, of whom Lord Balfour, speaking in the House of Lords of the then recently established Water Pollution Research Board, said, "I ought to say that the director is Dr. H. T. Calvert, M.B.E., who is, I suppose, the highest authority on this kind of investigation that we possess;" Mr. John D. Watson, consulting engineer of the Birmingham disposal system serving over a million people, the largest activated sludge plant in the world now in operation; Mr. H. C. Whitehead, its chief engineer; Mr. John Haworth, general manager of the Sheffield plant, a unique and very effective and economical system known as the "bio-aeration" system, of which he is the designer; and Dr. H. MacLean Wilson, until recently the chief inspector of the West Riding of Yorkshire Rivers Board, who has worked such wonders in his district through securing the co-operation of industry. In a conversation with Dr. Calvert, in speaking of abandoning certain waters to pollution, he interrupted, saying with some warmth, "In England, we do not recognize that any streams should be abandoned to pollution." Consider for one moment the background of that remark. It was made by a responsible official of the Ministry of Health. It related to England, a small country, geographically, with only some 50,000 square miles of territory, less than two-thirds of the size of Minnesota; with a dense population of between thirty-five and forty million people; highly industrialized, the workshop of the world; and her streams are small, very small. She is dependent upon industry for her very life's blood. She is staggering under a colossal load of debt and is ever haunted by the sinister shadow of a huge unemployment. Such was the background of that remark. "In England, we do not recognize that any streams should be abandoned to pollution". Hats off to the plucky, bull-dog English resolution that somehow always carries on.

The Cost. The cost of the Twin City system will be as great as previously stated and yet, figured on a per capita per annum basis, it does not seem so very large. Mr. Childs has estimated this to be, for adequate treatment under existing conditions, about $1.40 per annum, or, per day, about two thirds the cost of one cigaret. And that includes everything—capital charges (including amortization), maintenance, depreciation, necessary replacements and operation.

In a suggested program covering a period of forty years certain

elements of cost will come and go, will wax and wane. For instance during the early part of the period the construction cost will be high and operation cost will be nothing or very low. Toward the end of the period, interest and amortization for works built during the early portion of the construction period will fade from the picture, and the principal if not the only remaining costs will be those of operation, depreciation, replacement and maintenance.

It must be borne in mind that the construction of the system will necessarily require considerable time. The money required for operation and maintenance during the early period of the construction program will, of course, be very small. The construction program from which the figure of $1.40 per capita per year was computed provides that the money raised by a 1.5 mill tax levy would be used largely for construction purposes, thereby reducing the amount of the bond issues which would otherwise be necessary. The maximum of the bonds outstanding at any time (1942), according to this program, would be about $6,100,000. If all the construction has to be cared for by bond issues, the tax levy required in later years would, for a period of time, at least until the bonds have been retired, exceed the $1.40 per capita per annum.

The suggested program contemplates the completion of the intercepting sewers and the construction and operation of such part of the treatment plant by 1940 as will maintain the river below the confluence of the St. Croix in a condition congenial to fish life. Possibly full treatment may not be required until many years thereafter.

The objective is a fairly clean stream below the St. Croix by 1940 and capital expenditure, construction and operation will be marshalled and employed with that end in view. An initial tax levy of 1.5 miles is suggested, to be increased from time to time as interest charges on bond issues, amortization, operation, etc., increase, but at no time will this levy exceed 2 mills on the dollar of assessed valuation which, translated into per capita terms, means $1.40 per annum—the figure above stated.

It will be noted that the basic idea of this suggested program is the utmost possible utilization of the yearly tax levy over the long period of forty years with its resultant minimum employment of bond issues, coupled with a pace of construction and operation in step with the requirements of the objective, to wit, a fairly clean stream from 1940 onward. Of course, this suggested program is only one of many that are possible but it is one that is admirably adapted to cushion the financial shock to the tax payer.

Cost Apportionment. Though public sentiment was very strong in favor of the project, an agreement of the three communities concerned on some equitable division of the cost was a practical prerequisite to any legislation authorizing the construction and operation of the proposed system. A bill for such legislation was intro-

duced in the 1929 legislature but, unfortunately, failed of passage for lack of such agreement. This is especially to be regretted because of the involved delay of two years until the next legislature in 1931. However, very great efforts are now being made to effect such agreement, and the outlook at this writing seems promising.

The Crux of the Problem. Various plans of cost apportionment have been considered. The crux of the problem, seemingly, has to do with the wastes of the meat packing industry. That industry seems to contend that the cost of treating its waste, estimated at about $170,000 per year, should be a general charge on the whole proposed sanitary district, the same as in the case of domestic sewage or the wastes from other industries or, at all events, that a considerable proportion of such cost should be so defrayed. It has been noted that the packing plants' waste amounts to 24% of the entire pollution load of the district. Hence the great difficulty and seriousness of the question. The down stream communities in Minnesota and Wisconsin have up to this time, with admirable tact and delicacy, left with the Twin Cities the initiative in remedial measures and with great patience have endured a pollution situation that is ever growing more serious. It is now felt that if those cities can not before the sitting of the legislature in January, 1931, agree on some program, further forebearance will cease to be a virtue and it will be time for the State at large to take a hand.

In Conclusion. Such is, in a rough way, the present status of the Upper Mississippi pollution problem. It is very much to be regretted that the situation is as bad as it is, but it is, nevertheless, not without hope. It seems altogether probable that in the coming spring actual construction of a disposal system will be begun and will be rushed with all reasonable dispatch to completion. The Twin Cities have always been very sensitive on the score of public health and because of that fact, have the lowest death rate in the nation. They are now becoming, it is believed, equally sensitive on the score of river pollution. Their sense of fairness and decency is impelling them to see to it that the river leaves them as clean as it comes to them. This is doing unto others as we would have others do to us. *It is the Golden Rule of the River.*

POLLUTION PROBLEMS IN ONTARIO

H. H. MacKay

Biologist and Director, Fish Culture Branch,
Department of Game and Fisheries, Ontario

Although, generally speaking, the waters of Ontario are not subjected to the same degree of pollution as those of the more industrialized States of the United States, lying opposite and to the south of our boundary lines, nevertheless, with the increasing industrialization of the cities and towns of Ontario, the problem of disposal of trade waste is one which calls for more than an ordinary amount of vigilance if we are to preserve fish, and the life on which fish depend, from its destructive effects.

At least twenty-nine years ago Professor A. P. Knight, formerly of Queen's University, Kingston, and now retired, carried on experiments in the laboratory and in the field, to show the effects of saw-dust, waste water from pulp mills, gas works and nail factories on fish of various species. Subsequent studies were made by Professor Knight on the "Effects of Saw-dust on Fish Life," and were published in the Thirty-Ninth Annual Report of the Department of Marine and Fisheries, Fisheries Branch, as "Further Contributions to Canadian Biology" 1902–1905.

Apart from these studies, excepting research in connection with the utilization of wastes by certain industries, particularly pulp and paper mills, and presumably from the economic standpoint of the industries concerned, nothing definite in the line of research on pollution from the standpoint of harmful effects on fish life was done, so far as the writer is aware, until 1926 when the Fish Culture Branch of the Ontario Department of Game and Fisheries took a forward step in this direction.

In this connection, it should be stated that most, if not all, the Anglers' Associations throughout Ontario, now federated in one impressive body, known as the "Ontario Federation of Anglers," are co-operating either directly or indirectly along these lines, imbued, like all seriously concerned, with a high conservational sense of the importance of keeping our lakes and streams suitable for fish, free from foreign deleterious substances and, therefore, clean and beautiful. In fact, many of the active members of such Associations are connected in one way or another with industrial plants, responsible for the control of trade wastes.

The Dominion Act respecting Fisheries and Fishing has prescribed the following regulation in Chapter 73, Section 45, under the caption "Injury to Fishing Grounds and Pollution of Rivers."

> "No one shall throw overboard ballast, coal ashes, stones or other prejudicial or deleterious substances in any river, harbor, or roadstead or any water where fishing is carried on, or throw

overboard or let fall upon any fishing bank or ground, or leave or deposit or cause to be thrown, left or deposited, upon the shore, beach or bank of any water or upon the beach between high and low water mark, inside of any tidal estuary, or within two hundred yards of the mouth of any salmon river, remains or offal of fish, or of marine animals, or leave decayed or decaying fish in any net or other fishing apparatus.

"2. Such remains or offal may be buried ashore, above high water mark, and at establishments situated inside the mouths of rivers for carrying on deep-sea fisheries, the same may be dropped into perforated boxes or inclosures built upon the beach, or under stage-heads, in such manner as to prevent the same from being floated or drifted into the stream, or may be disposed of in such manner as any fishery officer prescribes.

"3. No person shall cause or knowingly permit to pass into, or put or knowingly permit to be put, lime chemical substances or drugs, poisonous matter, dead or decaying fish, or remnants thereof, mill rubbish or saw-dust or any other deleterious substance or thing, whether the same is of a like character to the substances named in this section or not, in any water frequented by fish. 1914, c. 8, s. 44."

Sections 77 and 78 deal with penalties as follows:

"Every one who, contrary to the provisions of this Act throws overboard ballast, coal ashes, stones or other prejudicial or deleterious substances in any river, harbor or roadstead or any water where fishing is carried on, or throws overboard or lets fall upon any fishing bank or ground, or leaves or deposits or causes to be thrown, left or deposited, upon the shore, beach or bank of any water, or upon the beach between high and low water mark, inside of any tidal estuary, or within two hundred yards of the mouth of any salmon river, remains or offal of fish or of marine animals, or leaves decayed or decaying fish in any net or other fishing apparatus shall be liable, for each offence, to a penalty not less than twenty dollars and costs and not more than one hundred dollars and costs, or to imprisonment for a term not exceeding two months; and every one so offending whether master or servant, and the master or owner of any vessel or boat from which such ballast or offal, or other prejudicial substance is thrown, shall be liable to penalty and imprisonment as aforesaid for each offence. 1914, c. 8, s. 75."

"Every person who causes or knowingly permits to pass into, or puts or knowingly permits to be put, lime, chemical substances or drugs, poisonous matter, dead or decaying fish or remnants thereof, mill rubbish or saw-dust or any other deleterious substance or thing, whether the same is of the like character to the substances named in this section or not, in any water frequented by fish, shall be liable for the first offence, to a penalty of twenty

dollars and costs, for the second offence, to a penalty of not less than forty dollars and costs, and not more than eighty dollars and costs, and also in addition thereto a further penalty of not less than ten dollars and not more than twenty dollars for every day during which such offence is continued; and for the third or any subsequent offence, to a penalty of not less than one hundred dollars and costs, and not more than two hundred dollars and costs, and also in addition thereto a further penalty not exceeding twenty dollars for every day during which such offence is continued. 1914, c. 8, s. 76."

Intensive surveys of centres of suspected pollution is one way of dealing with the situation, in order that we might be in a position to recommend, intelligently, control measures, and effect thereby the enforcement of the regulations. This is the method which the Branch has adopted.

In these studies standardized field methods are used in order to leave the way open for legitimate comparisons. The studies included determinations in lineal series above and below the source of suspected pollution, wherever practicable, as follows,—*Water analyses, for dissolved oxygen (Nessler's method); dissolved carbon dioxide; alkalinity; total acidity; pH (Standard Colormetric Method); plankton, qualitatively and quantitatively, using the Juday plankton net; bottom fauna using the Ekmann dredge; character of the aquatic plants, emergent and submerged types; the fish present in the various zones chosen for study, obtained by use of suitable gill nets, seines or dip nets.

Up to the present time, preliminary studies have been carried out at the following centres of suspected pollution located on lakes or streams: Sarnia, Chatham, Bridgeport, Burlington Bay, Bridgeburg, Lindsay, Peterborough, Barrie, Midland, Huntsville, Sturgeon Falls, Temiskaming, Haileybury, Timmins, Iroquois Falls, Smooth Rock Falls, Kapuskaing, Sault Ste. Marie, and Kenora.

The following table gives in some detail the results of the above individual investigations:

*A Kemmerer water bottle was used for collecting water samples below surface depths.

Date	Centre of Suspected Pollution	Character of Waste	Extent of Pollution From Source	Probable Effects of Pollution on: Dissolved Oxygen	Probable Effects of Pollution on: pH.	Bottom Fauna	Plankton	Vegetation	Fish
June 6	Sarnia	Waste acid from galvanizing plant; waste oil from Imperial Oil Co.							
June 7–11	Chatham	Town sewage and waste from Dominion Sugar Co.	Area of pollution localized to river at Chatham and for about 1–2 miles below to sugar mill docks.	None	None	Chironomid larvae, O. Planorbis, O. Oligochaetes, O. Nematodes, R.	Oscillatoria, O. Dinobryon, V.A. Anuraea, V.A. Diatoms, R. Crustaceans, R. Organic debris, F.		
	Bridgeport	Distillery waste, causing organic pollution.	Small portion of stream and pool at Schneider's Road.	Reduced from 5.6–1.1	Reduced 7.9–7.5	Majority destroyed, no insects.	Rotifers Protozoa Diatoms	Plants killed by suffocation.	Many dead carp and suckers seen along bank.
June 20–25	Burlington Bay	Mostly coal dust from extensive docks, also oil and dirt from storm sewers.	Pollution not considered serious and restricted to area around docks 200–300 yards from shore probable limits.	Slight decrease	None	Oligochaetes, A. Chironomids, R. Small snails, A. (Planorbis, Goniobasis, etc.).	Anuraea cochlearis, A. Diatoms, A. Oscillatoria, R. Crustaceans, O-R Organic debris, A.	Covered with a dirty sediment.	No definite harm done. Perch numerous also dace and suckers near docks.
June 17–20	Bridgeburg	Seepage from large coal pile owned by C. N. R.	Pollution extends at least ½ mile down from source of Frenchman's creek.	Distinct reduction	Reduced 6.7–3.8	Killed	Killed	Killed	Killed; many dead fish seen; including suckers, bass, shiner, and catfish.
	Lindsay	Saw-dust and sewage.	Six to seven miles below source.	Reduced from 6.1–2.8, 2 miles below Lindsay	Slight reduction	Absent	Abundant	Abnormal, brownish	
Aug. 14–19	Peterborough	Animal refuse from Canadian Packing Co.	Small area near packing plant radius 200 feet perhaps less, yet very dirty.	None	None	Owing to stony bottom, no samples of life obtained.		No notceable effect.	

Date	Centre of Suspected Pollution	Character of Waste	Extent of Pollution From Source	Probable Effects of Pollution on		Bottom Fauna	Plankton	Vegetation	Fish
				Dissolved Oxygen	pH.				
July 1–4	Barrie	Tannery waste, town sewage, oil from gas works, some coal dust.	One-half to one mile down bay from tannery outlet. This would cover area affected by the sewage which appeared to be much less than 200 yards from sewer outlet.	Decrease within 50 yards of outlet.	Slight increase near outlet.	Smothered by hair and organic matter from tannery.		Covered with dirt or sediment.	Herring and whitefish seem A, also carp and and suckers. Whitefish stomachs contained 90% Sphaerium shells.
June 26–30	Midland	Pulp from fibre board mill, chaff and dust from grain elevators, town sewage, coal dust.	Pollution restricted to water along shore and industrial area; 200–300 yards probable area.	No apparent effect.	Slight decrease 7.2–6.8 in places.	Scant, a few Chironomids.	No apparent effect, good variety of normal forms. Diatoms, A. Crustaceans, F. Protozoa, R. Cyanophyceae, F-R. Aphanocapsa, R. Chlorophyceae, O. Rotifers, F. (Anuraea Polyarthra) Organic debris, A.	No apparent effect; haul indicates moderate amount, but many normal species.	Not plentiful, but this cannot be attributed definitely to the slight pollution.
July 4–8	Huntsville	Tannery waste, town sewage.	About 1–2 miles of river below tannery and ½ mile below sewer.	Slight, if any.	Slight decrease near outlet.	Some snails, life scarce except for a few snails.		Dirty	No definite information; suckers plentiful and a few perch near tannery outlet.
Aug. 4–7	Sturgeon Falls	Bark and waste pulp from Paper Mill (Abitibi Co.)	From mill to mouth of river 4 miles, and some distance into Lake Nipissing, indefinite.	None apparent.	None apparent.	Campeloma A, little else; much bark and pulp sludge on bottom. Bottom much cleaner above mill though bark is present.		Scanty and dirty.	General decrease in sturgeon.

Date	Centre of Suspected Pollution	Character of Waste	Extent of Pollution From Source	Probable Effects of Pollution on		Bottom Fauna	Plankton	Vegetation	Fish
				Dissolved Oxygen	pH.				
Aug. 8–11	Temiskaming	Bark and waste pulp from International Pulp Mill.	Owing to rapids below mill, bark, etc., is carried down for 6–7 miles and settles out near Beauchene and beyond for some miles.	Reduced in phite strea ½ mile alo side of river, ery takes	acid sul- m for about ng Quebec when recov- place.	Large numbers of round worms and some Chironomids (C. plumosu in pulp and sludg at Beauchene; Hirudineae Chironomid larva Oligochaetes Sphaerium. Asellus also A.	Scarce but normal. s), e e		Trout said to be plentiful in Ottawa River and Gordon's creek.
Aug. 1–3	Lake Temiskaming at Haileybury	Pulp from Northern Canada Power Pulp Mill.	There is a visible deposit of pulp along lake shore with area of 1–2 acres. This extends out into the lake for a radius of 300–400 yards.		Slight reduction 7.0–6.8 near shore.	Very little life in area of pulp, chironomidae; few elsewhere, occasional insect larvae.		No vegetation in area examined, depth 50–180 feet.	Fish reported scarce throughout lake.
July 24–30	Timmins	Crushed rock from mines causing mechanical or physical pollution.	The 'tailings' or crushed rock has been run into Porcupine creek and has reached Porcupine lake, the bottom of which is practically covered throughout with a deposit of this material.	None	None	Smothered	Oscillatoria, A. (abundant in lake Porcupine) Spirogyra, A.	Abundant, large beds of lilies, reeds and potamogeton, not affected.	Suckers, perch, A; minnows, O. (60–70 small in seine haul).
July 30–31	Iroquois Falls	Pulp and bark from Abitibi Mill.	Bottom of river is very dirty with pulp and bark for at least six miles.	Reduced 100 yds. below mill 2 miles below mill 400 yds. below mill	4.0–6.2 4.5 4.2–7.0	Very scant.	Pulp fibres, A. 5 miles below mill but more disintegrated. Vorticella, F. Definite decrease of plankton in quantity and species with increase of pulp waste, 1¼ mile below mill.	Along shore dirty with a scum.	Scarce for some miles below mill.

Date	Centre of Suspected Pollution	Character of Waste	Extent of Pollution From Source	Probable Effects of Pollution on		Bottom Fauna	Plankton	Vegetation	Fish
				Dissolved Oxygen	pH.				
July 21–23	Smooth Rock Falls	Bark and pulp from Abitibi pulp mill.	There is much bark, wood trash and pulp for 7 miles down the river and it is reported to extend for 12–15 miles further.			Almost none Chironomid larvae, A.	Scant	Very dirty with deposit of old pulp and trash along bank.	Decided decrease in sturgeon and pickerel reported during last 5 years.
July 18–20	Kapuskasing	Waste from paper mill	Very little waste, hence practically no pollution.	River regai condition a feet below s	ns normal bout 100 ewer.	Owing to heavy r for some miles, n but river does no marked polluted mill than above.	apids below mill o tests were made t show any more condition below		
July 11–17	Sault Ste. Marie	Waste from paper mill and also from Algoma Steel Corporation. Town sewage.	There is practically no pollution of any sort. This is partly owing to the large flow of water, which exists in the river. The effluent from the Algoma Steel Plant sewer was normal in oxygen and pH., though reddish and somewhat turbid.	5.8–6.2	None	Seems normal 6 mayfly nymphs 7 Chironomid larvae 8Shells (Physidae) 1 mile below paper mill.	} in one dredging		Fish are reported plentiful in the river and can be caught 400 yards below mill.
	Kenora	Waste from paper mill.	River is polluted for about 8 miles below mill, the worst section extending approximately 5 miles.	None	None	Mostly Chironomids and Oligochaetes	Cyanophyceae, A. Diatoms, A. Protozoa, F. Rotifers, F. Copepods, O. Cladocerans, R.		Ciscoes, ling, perch and suckers common. Pike, pickerel, sauger and whitefish scarce.

Refer to extensive report prepared by Mr. R. A. McKenzie on "The Reported Decreases in Fish Life and the Pollution of the Winnipeg River, Kenora, Ontario."

V. A.—Very abundant. A.—Abundant. F.—Frequent. O.—Occasional. R.—Rare.

Summary and Conclusions

1. Water samples taken from four waters suspected of being polluted showed severe oxygen reduction; six showed slight oxygen reduction and seven showed no oxygen reduction.

2. In one case the pH showed an extreme lowering to the acid side of neutrality.

3. Pollution plankton such as certain infusoria, namely, Paramoecium, Colpidium, Carchesium and Vorticella, and the amoeboid protozoan, Difflugia, and the flagellate Euglena viridis were not present excepting in one instance, namely, the frequent occurrence of Vorticella in pulp and bark polluted waters at Iroquois Falls. The amoeboid protozoan, Arcella vulgaris, was also found frequently in this instance. The latter is usually found on bottom sediments or adhering to decomposing plants. (See A Study of the Pollution and Natural Purification of the Ohio River.

   1. The Plankton and Related Organisms, by W. C. Purdy, Washington Government Printing Office, 1923, and Investigation of the Pollution and Sanitary Conditions of the Potomac Watershed Plankton Studies, by W. C. Purdy, Hygienic Laboratory Bulletin, No. 104).

   Plankton Studies in the waters of the Winnipeg River as shown by Mr. R. A. McKenzie, while Field Investigator for the Department of Game and Fisheries, appear to show some relationship between plankton and the amount of waste matter, qualitatively and quantitatively. The same condition appears to hold for the waters examined at Iroquois Falls.

   The rotifer Anuraea considered by Purdy, 1923, loc. cit., to be a clean water organism was found in every case where the plankton was examined.

4. The presence or absence of bottom organisms appears to be the best general index of pollution or contamination. Chironomus plumosus and Ascellus vulgaris, forms tolerant to a reduced oxygen supply, occurred in three instances.

5. Vegetation was definitely discoloured or killed in eight instances.

6. Fish were killed in two instances, namely: carp at Bridgeburg and suckers, bass and catfish at Bridgeport.

7. The steps taken by or recommended to the industries are given in the last column of the accompanying table and it would appear that one solution for controlling wastes of an organic, chemical or mechanical type is the economical utilization of the wastes by the industries concerned.

Provision for screening out fibrous materials, or filtering harmful substances, or ponding in case of effluents containing harmful substances for the purpose of precipitating these, or aerating the effluents, is recommended in each particular case where necessary, but it should be remembered that the actual structure of these devices or

research along these lines is the work of mechanical engineers as well as biologists.

Mr. H. J. Dignan, B.A., Science Instructor, Port Hope High School, and Mr. P. W. Smith, M.S., formerly of the Department of Botany, University of Toronto, were responsible for the field work, and individual reports on the majority of the investigations, under the direction of the writer, and appreciation of their work is hereby acknowledged.

WATER POLLUTION IN ONTARIO

A. E. Berry

The pollution of natural waters is a problem which may be approached from a number of different angles. In this brief paper it is proposed to discuss only those conditions which are found in the Province of Ontario, and to indicate some of the measures which are being taken, as well as the possible effects these may have on those factors of interest to fish life.

To those who are familiar with this Province it will be readily apparent that the population is not, in general, greatly concentrated; that the area is a large one, and that there are numerous lakes and water courses. Most of these are of large volume, bordering the Province and draining the various watersheds. The result of this is that pollution of the water supply has not, as yet, in general, reached the same dangerous condition as is to be expected in some of the more thickly populated areas and especially where difficult trade wastes must be dealt with as well as domestic sewage.

The Province of Ontario is not an industrial centre of great magnitude when compared with many parts of the United States and Europe. Areas of concentrated population are not numerous. There are, however, a number of situations in which care must be exercised, and treatment of the wastes carried out to a fine degree if the water courses are to be adequately protected, both for fish life and public health purposes.

Pollution From A Public Health Viewpoint

In view of the writer's contact with public health activities and unfamiliarity with fish culture requirements, this paper must of necessity deal with pollution from a public health viewpoint. Adopting this plan it may be pointed out that the Ontario Department of Health is primarily concerned with water supply pollution from three specific angles, viz.:

1. To protect water supplies which are to be used for drinking and domestic purposes.
2. To protect streams and water courses so that they will not give rise to offensive odours, or unsightly conditions.
3. To protect those waters used for recreational purposes, such as in the lakeland regions of the north and to preserve their original purity as far as possible. It is well recognized that any extensive pollution of these waters greatly reduces their attractiveness to holiday seekers.

Legislation

In order to carry out this protection of the streams it may be well at this point to cite the legislation under which this matter is dealt with in the Province of Ontario. Most of this legislation comes within the "Public Health Act." In this Act the Provincial Depart-

ment of Health is given control over water supplies and sewerage systems in the Province. No municipality can establish, or extend, a waterworks system or a sewerage system without first having the sanction and approval of the Department. The Department is also empowered to go a step further and to compel any municipality or company to install a complete new system, purification works, or to make any alterations or extensions as may be deemed necessary by the Department in the interests of public health. This, it is apparent, enables the Department to maintain a close supervision over the water supplies and the sewage effluents of the various municipalities.

The Public Health Act also provides against the pollution of any lakes, rivers, streams, or other waters by garbage, excreta, manure, or other filth. Provision is made against the pollution of waters by passenger boats, or other vessels, or by the residents of health resorts, or summer areas. Within recent years an addition has been made to this Act whereby a riparian owner on any natural water course, who feels that the water is polluted to his detriment, and is causing any injury to him in the normal use of the supply, may apply to the Provincial Department of Health for an inquiry. The Department following this request makes the examination, and reports as to who are the offending parties, and as to how this pollution may be abated. The riparian owner, upon receipt of this report, may take action in the court to secure an injunction against the offending parties. Action has already been successfully taken in one instance where such pollution did occur. This is an important part of the Act in that it gives the right to any riparian owner, and at a minimum of trouble and expense, to take action againts those causing pollution of a water course. The requirements in this Act dealing with the pollution of lakes and streams in summer resort areas make possible the supervision by the Department of the methods of sewage disposal at summer hotels, cottages and on boats. This is useful in that even a small amount of pollution here would be detrimental.

The public health legislation of the Province as it affects natural waters has, in general, proven to be quite satisfactory. The enforcement of these laws is a responsibility which the Department of Health endeavours to have carried out.

Drinking Water Supplies

In dealing with water supplies intended for drinking purposes, gross pollution such as might injuriously affect fish life is seldom encountered. Such waters would not be considered satisfactory for domestic use, even when filtered and chlorinated. It is seldom that the dissolved oxygen content of these supplies reaches a point sufficiently low to affect fish life contained therein.

There are today some 300 public waterworks systems in operation in this Province. The majority of this water is drawn from surface supplies. The result of this is that care must be and is exercised to

exclude from these, as far as possible, all sewage contamination, trade wastes and like matter which might be injurious to the palatability or safety of the water when delivered to the consumer. More interest is evident in the B.Coli content of the water than its dissolved oxygen content. This supervision over the larger surface waters, while primarily for public health purposes, must exert a very strong influence on the maintenance of suitable fish life conditions.

This is the condition which holds today in these surface waters from which supplies are drawn for domestic use. True, there are some cases in which trade wastes are discharged untreated. This is particularly found in some northern waters where use for domestic purposes is only a minor consideration. The major source of contamination here is probably wood fibres. While this may be important in the protection of fish life it seldom becomes a public health problem. In other places the discharge of wastes may create an oxygen depletion in a localized area adjoining the point of discharge, but is generally very small in comparison with the entire volume of the stream or lake.

In the smaller streams of the Province the situation with respect to pollution is somewhat different. Public water supplies are seldom taken from small streams. There are a number of reasons for this. It is exceedingly difficult to prevent contamination of these waters from agricultural drainage and similar wastes, even though municipal sewage be excluded. These streams also have a tendency to dry up in the summer season, and in addition to this the water is quite warm and unpalatable for domestic purposes. Whether or not these waters would be of use for fish life remains to be seen. It would seem apparent, however, that a great many of the smaller streams of this Province are to-day experiencing periods in which the water is exceedingly low and are much less attractive for the maintenance of fish life than they were a number of years ago. Under these conditions the discharge of much sewage contamination must be prevented, even though these waters are not used for domestic purposes or support of fish life. If pollution to any appreciable extent takes place offensive conditions are likely to arise in the summer months. During the remainder of the year the stream may be quite able to take care of these wastes. Obviously the measures to be adopted in these cases are greatly different from those in the larger streams less likely to be influenced by summer conditions.

Sewage Disposal in Ontario

Sewage treatment in Ontario is progressing favorably. Unfortunately there are a number of municipalities which have been for years discharging raw sewage into the lakes and streams. These, however, in practically every case, empty their wastes into large bodies of water and the results do not indicate very objectionable conditions, except in the immediate vicinity of the outfall. It is also very diffi-

cult to induce municipalities to spend large amounts of money on sewage treatment when they have been discharging raw material into these waters for a number of years without apparent injury. The Department has, however, in recent years not permitted any new sewerage systems to discharge wastes into even the larger waters without some degree of treatment. Where the volume of water is extensive a minimum treatment is permitted; in others the most complete treatment is asked.

Viewing the situation in general it may be said that sewage disposal in Ontario has been more generally adopted than in the majority of provinces and states of this continent. Where the streams are small, or where local conditions are unfavorable the treatment of sewage has generally been by the activated sludge system; a system which is recognized as being capable of delivering a very highly satisfactory effluent. In a great many cases this effluent is better than the stream into which it is being discharged. It has a high relative stability, a high oxygen content, and should be non-injurious to fish life. There are, perhaps, a greater proportion of plants of this type operating in Ontario than in any other comparable province or state. The installation of these works is doing a great deal to preserve the sanitary qualities of the streams.

Activities of the Department of Health

The general situation with respect to stream pollution in Ontario has been outlined above. It might be of interest to point out what measures are being taken by the Provincial Department of Health to correct any existing unfavorable conditions, as well as to preserve for the future a condition in our streams, which will not only be adequate from a public health standpoint, but will likewise react to the advantage of fish life maintenance.

Taking advantage of the public health legislation, the objective of the Department of Health is to preserve the purity of the streams. It is hoped to be able to do this without undue attacks upon municipal finances and industries operating in the Province. This policy is being carried out in part by periodic examinations of sewage treatment works, and by investigations of those streams most likely to be injuriously affected. Inspection of sewage disposal works not only assures the Department that satisfactory effluents are being discharged, but it also serves as a means for training the plant operators. The Department has a staff of trained engineers available for this purpose. Stream pollution investigations of recent years have likewise served to inform the Department as to what measures should be adopted for any particular locality. Last year a thorough study of the Avon River, near Stratford, led to the conclusion that only an enlargement of their existing sewage works would suffice. This has since been completed, and it is anticipated that the pollution in this small stream will be cleared up. Studies have also been made on the

Grand River, in the vicinity of Kitchener, on the Thames near London, on the Detroit River near London, and on Lake Erie at Crystal Beach. These investigations have been made both with respect to colon contamination and oxygen depletion. It is gratifying to know that oxygen depletion has been a localized condition only. The results from the Grand River study show that the temporary discharge of only slightly treated sewage, while a disposal plant is being constructed, has caused an oxygen depletion for a very limited number of miles down stream.

One of the difficulties today with the small streams is the discharge of factory wastes, particularly from dairies and canning factories. In the majority of cases, however, these streams seem too small to support fish life. The objections encountered here are the offensive odours given off by this material when allowed to form in stagnant pools in the ditches. The material is so very difficult to treat and the cost is proportionately so great that an effort has been made where conditions will permit to carry it to a larger body of water and to give only the minimum treatment at the factory. This works to advantage for generally the volume of waste from the factory is comparatively small.

Water pollution in the recreational centres of the Province has been given careful supervision by the Department of Health. The great lakeland areas of Muskoka, Georgian Bay, and Lake of Bays have been carefully covered by representatives of the Department stationed there during the summer season. From this work the discharge of raw sewage to the lakes from various sources has been stopped, and the water today is in excellent condition, except at shore where it is subject to minor pollution from land drainage and bathing.

Application of Public Health Activities to Fishing Interests

In conclusion it may be repeated that the work of the Provincial Department of Health is concerned with the quality of the waters for public health purposes. In the treatment of sewage and prevention of pollution with this object in view it would seem that the protection of fish life will be materially aided. If the streams can be sufficiently guarded to meet the requirements of health departments it should in most cases be even greater than that required by the fishing interests to serve their purpose.

THE REPORTED DECREASE IN FISH LIFE AND THE POLLUTION OF THE WINNIPEG RIVER, KENORA, ONTARIO

R. A. McKenzie

Introduction

The effect of industrial wastes on the conservation of our aquatic resources is rapidly coming to the fore in Ontario. Although an ever-increasing amount of scientific research is being carried on by industrial organizations on ways and means of saving more by-products, no corresponding amount of investigation has been made to render the final waste products harmless to the life in our streams and lakes. Neither is the effect of various types of industrial wastes on aquatic life thoroughly understood, although a good deal of very valuable work in this direction has been carried on in the United States. To date very little of such work has been carried out in Ontario.

The following is a report of a study which was made on the Winnipeg river, while the author was in the employ of the Ontario Department of Game and Fisheries.

The writer wishes to extend his greatest appreciation to Professor J. R. Dymond of the Department of Biology, University of Toronto, for his help and kindly criticism in the preparation of this paper. Thanks are due to Dr. D. S. Rawson, formerly of the University of Toronto, for his kindness in checking the identification of the bottom organisms obtained in the dredgings made during this study. The author much appreciates the kindness of Mr. H. H. MacKay, M.A., biologist and director of fish culture of the Department of Game and Fisheries, Province of Ontario, in presenting this paper to this Society.

Description of the River

The portion of the Winnipeg river studied is that part between Kenora and the Dallas rapids, which is shown in the accompanying map. The Winnipeg river drains Lake of the Woods via three outlets, which are known as the east branch Kenora, west branch Kenora and Island Falls. The most westerly outlet flows past the town of Keewatin. These outlets all unite some distance below their respective dams and falls, in an expanded part of the river.

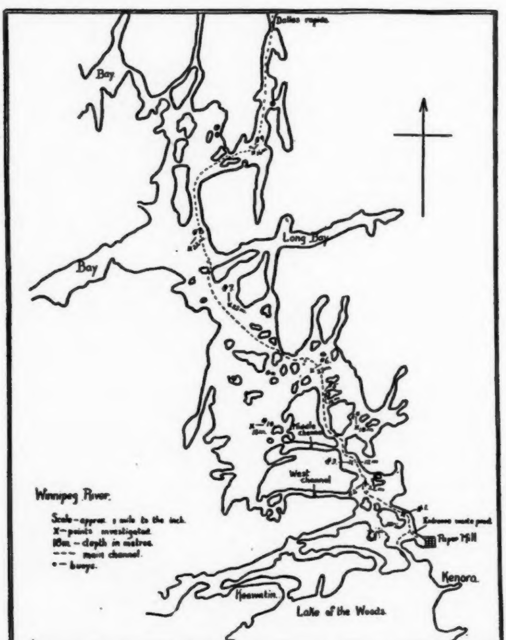
Power is developed from these heads of water by the Kenora Municipal Power Plant, Lake of the Woods Milling Co. and Keewatin Flour Milling Co. An idea of the amount of water leaving Lake of the Woods by these outlets may be obtained from Table No. 1. This information has been obtained from the Hydro-Electric Power Commission, fifth report, 1907, for the province of Ontario.

TABLE NO. 1

WINNIPEG RIVER

Stream	Head	Estimated Low Water Flow, C.F.S.	Min. 24 Hour Power, H.P.
E. Branch, Kenora	18	2,500	4,100
W. Branch Kenora, (Norman Dam)	18	11,000	18,000
Island Falls	45	14,500	59,300
Totals	81	28,000	81,400

Comparing the estimated low water flow for the Nipigon river, which is 5,500 c.f.s., with the total c.f.s. shown in the Table, it is seen that the Winnipeg river is a much larger stream, with a volume about five times as great.



The map also shows the broken up character of the river from the Lake of the Woods, downstream, as far as the "Dalles." The outlets unite just below the lake, but remain united only for a very short distance. A number of large islands separate the greatly expanded river into several channels which are themselves broken up by numerous small rocky islands.

These irregularities divide the river into a chain of large, deeper parts connected by narrow, shallow, swiftly flowing stretches. The channel as indicated on the map is not the only one possible, but it is the best and shortest route for the larger boats.

The shoreline is almost entirely rocky in nature, with few gravel beaches. The shore is not steep, as a general rule, except along the "Dalles," and one or two other narrow channels. The surrounding country is well wooded. These features are shown on the photographs.

Sources of Pollution

The Kenora Paper Mill is located on a bay just to the east of the eastern branch below the power dam. The logs are carried down a flume from a point above the dam into this bay, which is not subject to any strong currents. The refuse and waste from the mills enter the river well below the yards of the paper mill. The wooden waste conduit empties into the river below the surface about fifty feet from shore, and just at the head of a short rapid.

The Keewatin Flour Mills are situated on the west branch. The waste, consisting of dust and weed seeds, is blown out onto the riverbank where an attempt at burning it is made. The action of wind and rain carries this material into the river. The chief local complaint against this plant is in the dissemination of weed seeds, foreign to the locality.

The sewage from the two small towns is insignificant in a river of this size. The population of Kenora was 5,407 and of Keewatin 1,327, in 1921.

Water Levels

However, the change in water levels of this river must be harmful to aquatic life. It is understood that the International Waterways Commission has control of the dams which regulate the flow out of Lake of the Woods. An example of the fluctuation in the water level over a five-day period is as follows:—

October	8, 1928	–	1038.71 ft.
"	9, 1928	–	1040.11 "
"	10, 1928	–	1041.52 "
"	11, 1928	–	1042.10 "
"	12, 1928	–	1042.44 "
"	13, 1928	–	1042.72 "

These figures indicate a change of our feet in five days and, according to reliable reports, this is only one-half of that which occurs at times. These facts are borne out by the bare, scoured shores seen in the photograph. This condition is most disastrous to fish life, and steps should be taken at once to maintain a more uniform flow of water in the Winnipeg river, since it is not only harmful to the fish life but also to the muskrats in the Lake of the Woods.

Time of Study

This study was made over a period of about two weeks in October, 1928. A study of this kind should be carried out at intervals throughout the year, or failing this, preferably during the hottest part of the summer when the water is lowest. Unfortunately this was not done, but it is considered that the results of even so short a study give some indication of the effect of the pollution of the kind occurring here.

Methods

The results of pollution were studied by investigating the O_2 content and pH of the water, plankton, bottom organisms and fish found in different parts of the river. In selecting places for investigation an attempt was made to choose points representative of the different types of water areas, such as deep, slowly moving parts and swifter stretches, both near and farther removed from the source of pollution. The points chosen for investigation are shown on the map, but studies were carried out at other points than those indicated. Special efforts were made to trace the course of the pollution throughout all parts of the river.

The chemical tests made at most of the stations shown on the map were confined to an oxygen determination (Miller's method) and a pH determination (La Motte's colormetric method). The water samples used for this were taken from the bottom and surface. Bottom samples were obtained with a Kemmerer water bottle. The temperature of these samples was also recorded,—that for the bottom being taken with a pocket thermometer as soon as the bottle came to the surface. In taking plankton, surface tows were made possible by running the boat, driven by an outboard motor, in a small circle for five minutes. A total vertical haul was also made. Dredgings were made at the stations and at various places between, to check the material obtained at the stations and also to search out all the collecting points for the waste matter. A small Ekmann dredge was used in collecting the samples which were later washed through fine wire screening and then through cheesecloth. Samples of the fish fauna were obtained by setting a string of gill nets of varying sizes of mesh (1¼″–4½″) at three different points. More extensive settings should have been made, but the nets became very much torn with limbs and logs and too badly fouled with pulp, bark and chips during these three settings, to be very efficient.

Summary of Results

Chemical. The results are given in detail in appendix to this paper. Table No. II, summarizes some of these data.

A study of the following Table shows that there is comparatively little difference in the oxygen content of the water at the different stations. In all cases the oxygen content is well above the 2.5 c.c. per litre, which is supposed to be about the minimum for fish life. The total range between surface and bottom, as well as from station to station, is included between 7.0 and 8.1 c.c. This high oxygen content is no doubt due largely to the falls, etc., out of Lake of the Woods, the various swift stretches in the river and the thorough mixing of the water from top to bottom during the fall turn-over of the water. The pH content shows very little variation from bottom to top and throughout the various stations.

It is possible that, during the summer, because of more decomposition of organic materials, higher temperatures and smaller volume of flow, the oxygen content of the water may be reduced to figures considerably below those obtained during October.

TABLE NO. II.

This Table gives the water and air temperatures, together with the oxygen and pH content of the water samples taken at the stations whose distances downstream from the source of pollution are indicated in miles by the figures in the heading of this Table.

Station No.	2	4	5	6	10	7	8	9
Distance from Source of Pollution (In Miles)	1¼	2½	2¾	3½	4½	5	6½	8½
Surface oxygen	7.9	7.8	7.4	7.9	7.9	7.8	7.3	8.1
Bottom oxygen	7.9	7.8	7.2	7.8	7.75	7.5	7.0	7.9
Surface pH	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Bottom pH	7.3	7.3	7.1	7.3	7.3	7.3	7.3	7.3
Air temperature	49 F	40 F	42 F	45 F	47 F	48 F	40 F	46 F
Surface temperature	48 F	49 F	50 F	49 F	49 F	49 F	49 F	49 F
Bottom temperature	48 F	48 F	47 F	49 F	49 F	49 F	49 F	49 F

Plankton. In examining the plankton, the samples were all made up to the same volume first. The sample was then shaken and allowed to stand in a graduated cylinder for about an hour, when all the larger particles of waste material had settled out. The amount of this material that settled out of each sample was recorded.

In the microscopical examination of the plankton, no actual counts of the numbers of organisms were made, but the relative abundance of the individual species of plankton organisms was estimated and listed as abundant, frequent, occasional and rare. In preparing the tables these terms have been given numerical values as follows,— abundant = 4, frequent = 3, occasional = 2, rare = 1.

TABLE NO. III.

INDICATING THE RELATIVE ABUNDANCE OF THE ORGANISMS AT THE DIFFERENT STATIONS IN THE SURFACE WATER

Station No.	2	4	5	6	10	7	8	9
Distance from Source of Pollution. (Miles)	1¼	2½	2¾	3½	4½	5	6½	8½
Blue-green algae	6	3	4	15	13	6	6	3
Diatoms	14	11	15	19	19	19	16	12
Green algae	3	4	10	6	11	12	9	6
Protozoans	3	2	8	7	8	5	8	4
Rotifers	1	0	2	4	5	3	2	3
Cladocerans	0	1	0	0	0	0	1	0
Copepods	1	2	1	3	3	2†	1	2
Pulp material (in c.c.)	5½	4½	3	1½	*	*	¾	½

NOTE: * = small amounts.
† = immature stages not taken in account.

TABLE NO. IV.

INDICATING THE NUMBER OF SPECIES OF THE VARIOUS ORGANISMS IN THE SURFACE WATER AT THE VARIOUS STATIONS

Station No.	2	4	5	6	10	7	8	9
Distance from Source of Pollution. (Miles)	1¼	2½	2¾	3½	4½	5	6½	8½
Blue-green algae	3	3	3	6	5	3	3	3
Diatoms	6	6	7	9	6	7	7	5
Green algae	2	4	5	4	5	10	7	4
Protozoans	2	2	5	5	4	3	4	2
Rotifers	1	0	1	3	2	3	1	3
Cladocerans	0	1	0	0	0	0	1	0
Copepods	1	2	1	1	1	1	1	1

The results of these studies are recorded in Tables III and IV and Figure 1. From a perusal of these it is seen that the maximum amount of waste material was taken at Station No. 2, which is the closest to the source of pollution, and that there is a gradual decrease in the amount of this material until by the time Station No. 10 is reached there is very little trace of it in the surface water. As a result of the bottom studies, reported later, it was found that considerable quantities of coarser organic material (bark, chips and pulp) had settled on the bottom at Stations No. 1 and No. 2. At Stations No. 4 and No. 5, it was found, as a result of similar bottom

studies and vertical hauls with a plankton net, that the finer material had gradually sunk, and become concentrated in the lower layers of the water. Beyond these regions very little of this finer material was found. It is believed that it gradually decomposes while suspended in the bottom layers of the water and that the increased quantities of plankton found between Stations No. 5 and No. 9 are due to this decomposition. Figure No. 1 indicates that the plankton at Stations No. 5, No. 6, and No. 10 is decidedly greater in amount than at Stations No. 2 and No. 4, and that from this region to Station No. 9 the quantity gradually decreases to an amount approximately equal to that found at Stations No. 2 and No. 4. The curves also indicate, as was to be expected, that this effect is more marked in the case of the plant plankton. The animal plankton curve is in general similar to that for the plants, but it does not reach nearly such a high level, nor do the numbers fall off as rapidly. These findings are confirmed as a result of a number of vertical plankton hauls made from the bottom to the top at each station.

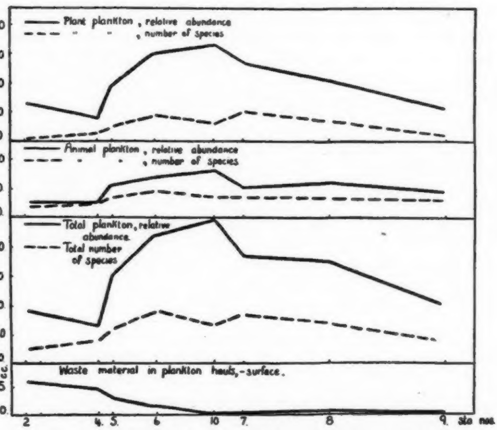


Figure no 1. Indicates the relative abundance of plankton individuals, the number of species and the amount of waste material in the surface water at the various stations

As suggested earlier, this rise in the quantity of plankton is probably due to the increase in the amount of available food material in the water, brought about by the decomposition of the finely divided organic material.

Bottom Fauna. The numbers of the different kinds of organisms collected as a result of the dredgings are given in Table No. V. The numbers given in the Table are the actual numbers of the different

organisms brought up by the dredge at the different stations. This dredge was 9 inches square, thus lifting 81 square inches of the bottom.

The Table indicates that at Stations No. 1 and No. 2 the bottom was covered at a considerable depth with a mixture of bark, chips, pulp, etc. No living organisms were found in any of this material. At Stations No. 3 and No. 4 the hard sand bottom was swept by a fairly swift current. The only organisms taken in the dredge were at Station No. 3, where the organisms indicated in the Table were found in large, empty bi-valve shells. Of the organisms found at the other stations it must be remarked that certain species of chironomids and oligochaets, when found in large numbers, have been said to be indicative of pollution. (Wiebe, 1927, and Richardson, 1921 and 1925.) These organisms are found in greatest numbers at Stations No. 6 and No. 7. The former is within three-quarters of a mile, and the latter within two and one-half miles of Station No. 5, at which, as stated previously, considerable quantities of finely shredded wood pulp were found in the bottom water. At Station No. 6 the bottom was covered by thick slimy mud-like decayed organic matter, and at No. 7 a much thinner layer of this same material covered a bottom composed of hard bluish clay. It is suggested that the zone where the organic waste is decomposing and the regions immediately below are rich in decayed organic matter and possess a lowered oxygen content. The conditions in these areas are usually favourable for the abundant production of certain types of organisms which are resistant and tolerant to a decrease in the oxygen supply. Although water samples taken at the different stations do not indicate any oxygen deficiency, it should be pointed out that the sampling methods do not permit the taking of samples closer than two or three feet from the bottom. Alsterberg (1922) has found that there may be oxygen deficiency at the bottom of lakes, which may not be evident in samples taken 1.5 to 2 metres above the bottom where the usual determination of bottom oxygen is made.

At Stations No. 8 and No. 9, there is a decided decrease in the number of chironomids and oligochaets and an increase in the number of other bottom organisms, as compared with Stations No. 6 and No. 7. This probably indicates a return to clean water conditions which are more favourable for the growth of clean water organisms such as caddis. Although Station No. 10 corresponds to No. 6 and No. 7 in its distance from the source of pollution, it is located off the line of the main current and probably does not receive nearly so much of the pulpy matter as these other stations. Its bottom fauna was found to be more similar to those of No. 8 and No. 9 rather than to those of No. 6 and No. 7. This is no doubt due to the lessened amount of decomposition as compared to the latter stations.

The details of the character of the bottom at each station were as follows:

TABLE NO. V.

INDICATES THE NUMBER OF INDIVIDUALS FOUND IN THE BOTTOM FAUNA AT THE VARIOUS STATIONS

Station No.	1	2	3	4	5	6	10	7	8	9
Distance from Source of Pollution. (In Miles)	¼	1¼	1½	2½	2¾	3½	4½	5	6½	8½
Pontoporei hoyi			2				4	3	3	
Caddis larvae			9						1	7
Hirudinea			1						2	
Hirudinea egg cases			1							
Hydra										5
Chironomus plumosus						12	3	7	7	
Chironomidae			2		8	3	3	50	15	2
Oligochaeta					3	100	4	2	5	
Valvata tricarinata					2	1	1			
Sphaeriidae (alive)					1	7	8	4	4	2
Sphaeriidae (dead)					2			3		
Campeloma sp.							2			

Station No. 1. Water from 2–3 metres deep, flowing swiftly over a bottom covered with bark, chips and pulp.

Station No. 2. Water about 22 metres deep, flowing slowly over a bottom consisting of 98% pulp, 2% sand. A vile odour given off from this pulpy material. A lot of fine pulp in suspension.

Station No. 3. Water about 18 metres deep and current quite rapid along one side of this small expanded section. Bottom of hard sand swept clean of everything except some large bi-valve shells.

Station No. 4. Water from 16–20 metres deep here flowing moderately swiftly over a bottom of rocks, stones (large) and fine sand. A lot of pulp in suspension.

Station No. 5. Water 12–15 metres deep, flowing slowly over a bottom of hard sand and rocks. Lot of pulp in suspension.

Station No. 6. There was no apparent flow in the water here which is from 25–28 metres deep. The bottom was composed of thick, slimy mud which seemed to be decayed organic matter. Very little actual pulp.

Station No. 10. Water about 13 metres deep at this station with no apparent flow. A lot of matter in suspension over a bottom composed of 90% thick, slimy mud, 2% fine pulp and 8% sand.

Station No. 7. There was no apparent flow to this water which was about 24–28 metres deep. Bottom composed of hard, bluish clay, covered with a thin layer of silt and fine decayed organic matter.

Station No. 8. The stream was 25 metres deep here and had no apparent flow. Bottom composed of ordinary mud or silt.

Station No. 9. The stream was moderately rapid here and about 16 metres deep. Bottom composed of hard sand.

As a result of this study of the bottom fauna of the river it has been found that the coarse material, bark, limbs and chips settle out in the deeper and less rapid parts of the stream within one and one-quarter miles. In this region all the bottom organisms are apparently blotted out. The finer material (wood-pulp) becomes concentrated in the bottom water in similar deep, slow moving parts of the river within three and one-half miles of its point of introduction. As a result of the decomposition of this fine material the oxygen content of the bottom water appears to become lowered as far as five miles from the source of pollution, as indicated by a large bottom fauna of chironomids and oligochaets. From this point clean water conditions gradually become re-established.

Fish Fauna. The results of the gill net catches at the three stations, at which nets were set, are given in Table No. VI. These results indicate that the nature or quantity of pollution does not make it impossible for fish to exist in the water at this period of the year. But the fact that fish were taken at these stations does not mean that they were securing their living there. The results of the plankton and bottom studies indicate that there was practically no food for ciscoes at Station No. 2, and yet considerable numbers were taken there. Whether they were at this point at this time in response to their spawning instinct is not known, but they are fall spawners.

TABLE NO. VI.

INDICATES THE ACTUAL NUMBER OF FISH TAKEN AT EACH STATION

Station No.	2	5	7
Distance from source of pollution	1¼	2¾	5 miles
Depth of water	22	12	23 metres
Type of bottom	Pulp	Hard sand	Mud
Ciscoes	27	4	35
Pickerel (S. vitreum)	1	2	3
Sauger (S. canadense)	1	—	—
Pike (E. lucius)	—	5	—
Perch	—	16	—
Whitefish	—	—	2
Ling	6	—	22
Suckers	5	16	15

Discussion

Although it has been shown that there is an increase in the quantity of plankton in a certain stretch of the river due probably to the decomposition of certain organic matter, and that on the bottom

there is an increase in certain bottom organisms and a decrease in others, also probably traceable to this decomposition, these facts do not necessarily mean that fish life will be increased or even maintained. The plankton organisms found in this water do not directly serve as food for the adults of any of the fish taken. Pickerel, saugers, ling, pike and perch can only make use of this material through the medium of smaller fishes or larger invertebrates, which consume this plankton. The conditions here may be such that small fishes, insect larvae and so on, cannot live. If such is the case no matter how much plankton exists fish production will not thereby benefit. As a matter of fact, observations indicated that there was a very great dearth of small fishes of all kinds, and that comparatively few insect larvae or other invertebrates of similar size existed.

The effect on the bottom fauna, which appears to be traceable to pollution, is (1) a total absence of bottom organisms for the first mile and one-quarter and (2) an increase in the numbers of chironomids and oligochaets at the expense of clean water forms. The destruction of bottom fauna in the first case is, of course, injurious to fish life. The increase in the above mentioned forms may be favourable to such bottom feeding fishes as suckers and whitefish, provided their young can live in the conditions here existing. It is interesting to note here that suckers were found in considerable numbers while whitefish were very scarce.

Summary and Conclusions

The Winnipeg river on which these pollutional studies were made is a very large river draining Lake of the Woods by way of three outlets. From the lake downstream it is broken up into three channels by islands for several miles, finally uniting into one at the "Dalles". At each of the outlets from the lake there is a dam or falls, thus giving aeration.

The waste material put into the river consists of bark, chips, pulp and waste liquors from the large pulp and paper mills at Kenora; cleanings from the Keewatin Flour Mills and sewage from these two towns.

The accompanying chart indicates comparatively the oxygen content, plankton and bottom fauna at the different stations. The width of the different figures is directly proportional to the amount of oxygen, the abundance of the plankton and the numbers of bottom organisms found at the stations indicated. The bottom organisms have been divided into two groups,—(1) chironomids and oligochaets, which are regarded as tolerant or resistant to pollution and (2) the remaining forms such as caddis, Sphaeriidae, etc., shown in Table No. V., which are more or less sensitive to pollution.

From this chart it is seen that no oxygen deficiency was found at any point investigated. The studies were made during October,

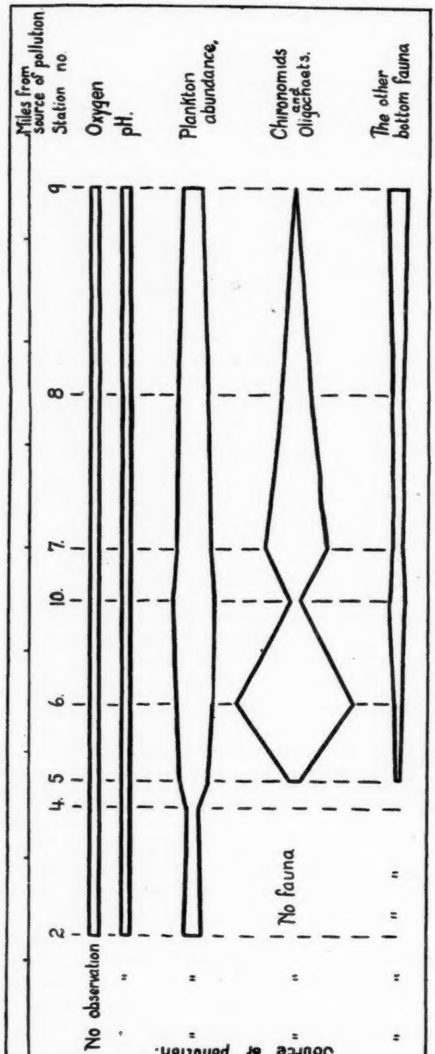


Chart no I. Indicates the oxygen and pH content of the water as well as plankton abundance, and bottom fauna distribution. The vertical ordinates indicate the relative proportions at the various stations of the items listed.

1928. It is possible that during the summer, due to higher temperatures and decreased water flow, oxygen deficiency may occur.

The coarser organic material, bark, chips and pulp settle to the bottom at Stations No. 1 and No. 2 within one and one-quarter miles of their introduction; the finer material, chiefly wood-pulp, becomes concentrated in the lower layers of the water at Stations No. 4 and No. 5, three and one-half miles below. The decomposition of this organic waste provides food material for plankton and bottom organisms.

The plankton, which decreases in abundance somewhat from Station No. 2 to Station No. 4, increases considerably between Stations No. 5, No. 6 and No. 10, i.e., below the point at which the finer organic material has settled and decomposed. From Station No. 10, where the maximum is reached, the plankton decreases gradually, until at Station No. 9 it is about equivalent to that at No. 2.

No organisms were found on the bottom, which was covered with bark, chips and so on, nor in the moderately swift flowing, shallow sections immediately below this region. At Station No. 5 where the wood-pulp had settled to the bottom water a few organisms were found. At No. 6 the bottom organisms had increased very considerably and from this point downstream they gradually decrease again. The majority of the organisms found at Station No. 6 were chironomid larvae and oligochaets which are considered to be forms resistant to pollution, and it is believed that their abundance at this point is due to the decomposition of the organic waste, as in the case of the plankton. Downstream from this point there is a decrease in the abundance of these forms and a gradual re-establishment of clean water forms.

The taking of fish in some numbers in the polluted sections of the stream is believed to indicate only that the nature or quantity of pollution does not make it impossible for fish to exist in the water at this period of the year.

The increased quantities of plankton and certain types of bottom organisms resulting from the decomposition of organic wastes is not regarded as being advantageous, except possibly to suckers. This certainly does not make up for the miles of stream rendered unsuitable for valuable fish through pollution.

APPENDIX

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AMERICAN FISHERIES SOCIETY

Organized 1870

CERTIFICATE OF INCORPORATION

We, the undersigned, persons of full age and citizenship of the United States, and a majority being citizens of the District of Columbia, pursuant to and in conformity with sections 599 to 603, inclusive, of the Code of Law for the District of Columbia, enacted March 3, 1901, as amended by the acts approved January 31 and June 30, 1902, hereby associate ourselves together as a society or body corporate and certify in writing:

1. That the name of the Society is the American Fisheries Society.

2. That the term for which it is organized is nine hundred and ninety-nine years.

3. That its particular business and objects are to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; to unite and encourage all interests of fish culture and the fisheries; and to treat all questions of a scientific and economic character regarding fish; with power:

(a) To acquire, hold and convey real estate and other property, and to establish general and special funds.
(b) To hold meetings.
(c) To publish and distribute documents.
(d) To conduct lectures.
(e) To conduct, endow, or assist investigation in any department of fishery and fish-culture science.
(f) To acquire and maintain a library.
(g) And, in general, to transact any business pertinent to a learned society.

4. That the affairs, funds and property of the corporation shall be in general charge of a council, consisting of the officers and the executive committee, the number of whose members for the first year shall be seventeen, all of whom shall be chosen from among the members of the Society.

Witness our hands and seals this 16th day of December, 1910.

SEYMOUR BOWER	(Seal)
THEODORE GILL	(Seal)
WILLIAM E. MEEHAN	(Seal)
THEODORE S. PALMER	(Seal)
BERTRAND H. ROBERTS	(Seal)
HUGH M. SMITH	(Seal)
RICHARD SYLVESTER	(Seal)

Recorded April 16, 1911.

CONSTITUTION AND BY-LAWS

(As amended to date)

ARTICLE I

Name and Object

The name of this Society shall be American Fisheries Society. Its object shall be to promote the cause of fish culture; to gather and diffuse information bearing upon its practical success, and upon all matters relating to the fisheries; the uniting and encouraging of all interests of fish culture and the fisheries, and the treatment of all questions regarding fish, of a scientific and economic character.

ARTICLE II

Membership

Active Members. — Any person may upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues become an active member of this Society.

The annual dues of active members shall be three ($3.00) dollars per year, payable in advance. In case of non-payment of dues for two consecutive years, notice shall be given by the Treasurer in writing, and such member remaining delinquent after one month from the date of such notice, his name shall be dropped from the roll of the Society. Such delinquent member, having been dropped for non-payment of dues, shall be ineligible for election as a new member for a period of two years, except upon payment of arrears.

Club Members.—Any sporting or fishing club or society, or any firm or corporation, upon a two-thirds vote of the members present at any regular annual meeting and upon the payment of one year's dues, may become a club member of this Society. The annual dues of club members shall be five ($5.00) dollars per year.

Libraries. — Libraries shall be admitted to membership upon application and the payment of one year's dues. The annual dues for libraries shall be three ($3.00) dollars per year.

State Memberships.—Any State, Provincial or Federal Department of the United States, Canada or Mexico may, upon application and the payment of one year's dues become a State member of this Society. The annual dues for State memberships shall be ten ($10.00) dollars per year.

Life Memberships. — Any person may, upon a two-thirds vote of the members present at any regular annual meeting and the payment of fifty ($50.00) dollars become a life member of this Society and shall thereafter be exempt from payment of annual dues. The Secretary and Treasurer of the Society are hereby authorized to transfer members from the active list to the list of life members provided that no member shall be so transferred unless he shall make request for such transfer and shall have paid dues as an active member of the Society for at least twenty-five years.

Patrons. — Any person, society, club, firm or corporation, on approval of the Executive Committee and the payment of fifty ($50.00) dollars or more, may become

a patron of this Society with all the privileges of a life member, and shall be listed in all the published membership lists of the Society.

Honorary and Corresponding Members.—Any person may be made an honorary or corresponding member upon a two-thirds vote of the members present at any regular annual meeting of the Society. The President (by name) of the United States, the Governors (by name) of the several States and the Secretary of Commerce of the United States (by name) shall be honorary members of the Society.

Election of Members Between Annual Meetings.—The President, Secretary and Treasurer of the Society are hereby authorized during the time intervening between annual meetings, to receive and act upon all applications for individual and club memberships. A majority of such committee shall decide upon the acceptance of such applications.

Voting.—Active members and life members only shall have the right to vote at regular or special meetings of the Society. Fifteen voting members shall constitute a quorum for the transaction of business.

ARTICLE III

Funds

Current Fund.—All moneys received from the payment of dues of active members, club members, libraries, life members, State members, sale of Transactions, contributions thereto, and from any miscellaneous sources, shall be credited to the Current Fund of the Society and shall be paid out only on vouchers regularly approved by the President and Secretary.

Permanent Fund. — The President, Secretary and Treasurer shall be the Trustees of the Permanent Fund. All moneys received from patrons, bequests and contributions thereto shall be credited to the Permanent Fund of the Society. Such fund shall be invested by the Treasurer in such manner as may be approved by the trustees of such fund. The members of the Society shall, at each annual meeting, determine the disposition of interest accruing from such investment.

ARTICLE IV

Officers

The officers of this Society shall be a President and a Vice-President, who shall be ineligible for election to the same office until a year after the expiration of their term; a Secretary, a Treasurer, a Librarian, and an Executive Committee of seven, which, with the officers before named shall form a council and transact such business as may be necessary when the Society is not in session—four to constitute a quorum.

In addition to the officers above named there shall be elected annually five Vice-Presidents who shall be in charge of the following five divisions or sections:

1. Fish Culture.
2. Commercial Fishing.
3. Aquatic Biology and Physics.

4. Angling.
5. Protection and Legislation.

No officer of this Society shall receive any salary or compensation for his services and no allowances shall be made for clerical services except by vote of the Society at regular annual meetings.

Duties of Officers.—The President shall preside at the annual and all special meetings of the Society, shall be ex-officio chairman of the Council of the Society, and shall exercise general supervision over the affairs of the Society.

The Vice-President shall act in the place of the President in case of absence or inability of the latter to serve.

The Secretary shall keep the records of the Society, attend to the publication and distribution of its Transactions, attend to its correspondence, promote its membership, and arrange for annual and special meetings.

The Treasurer shall receive and collect all dues and other income of the Society, shall have the custody of its funds and pay all claims which have been duly approved. The Treasurer shall furnish a bond in the sum of one thousand ($1,000) dollars to be approved by the Executive Committee and to be paid for by the Society.

The Librarian shall have the custody of the library of the Society, including its permanent records and printed Transactions, and shall have charge of the sale of surplus copies of such Transactions. Other officers shall perform such duties as shall be assigned them by the President.

ARTICLE V

Meetings

The regular meeting of the Society shall be held once a year, the time and place being decided upon at the previous meeting, or, in default of such action, by the Executive Committee.

ARTICLE VI

Order of Business

1. Call to order by the President.
2. Roll call of members.
3. Applications for memberships.
4. Reports of officers.
    a. President.
    b. Secretary.
    c. Treasurer.
    d. Vice-Presidents of Divisions.
    e. Standing Committees.
5. Committees appointed by the President.
    a. Committee of five on nomination of officers for ensuing year.
    b. Committee of three on time and place of next meeting.

c. Auditing committee of three.
d. Committee of three on program.
e. Committee of three on publication.
f. Committee of three on publicity.

6. Reading of papers and discussions of same.
(*Note*—In the reading of papers preference shall be given to the members present.)
7. Miscellaneous business.
8. Adjournment.

ARTICLE VII

Changing the Constitution

The Constitution of the Society may be amended, altered or repealed by a two-thirds vote of the members present at any regular meeting, provided at least fifteen members are present at said regular meeting.

AMERICAN FISHERIES SOCIETY
LIST OF MEMBERS, 1930-1931

(Showing Year of Election to Membership)

HONORARY MEMBERS

The President of the United States.
The Secretary of Commerce of the United States.
The Governors of the several States.
'08 Antipa, Prof. Gregoire, Inspector-General of Fisheries, Bucharest, Roumania.
'06 Besana, Giuseppe, Lombardy Fisheries Society, Via Rugabello 19, Milan, Italy.
'09 Blue Ridge Rod and Gun Club, Harper's Ferry, W. Va.
'93 Borodin, Nicolas, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.
'12 Calderwood, W. L., Inspector of Salmon Fisheries for Scotland, Edinburgh, Scotland.
'04 Denbigh, Lord, London, England.
'04 Kishinouye, Dr. K., Imperial University, Tokyo, Japan.
'88 Lake St. Clair Shooting and Fishing Club, Detroit, Mich.
'17 Mercier, Honoré, Minister of Lands and Forests, Quebec, Canada.
'09 Nagel, Hon. Chas., St. Louis, Mo.
'95 New York Association for the Protection of Fish and Game, New York City.
'08 Nordqvist, Dr. Oscar Fritjof, Superintendent of Fisheries, Lund, Sweden.
'06 Perrier, Prof. Edmond, Director, Museum of Natural History, Paris, France.
'92 Vinciguerra, Dr. Decio, Director, Royal Fish Culture Station, Rome, Italy.

CORRESPONDING MEMBERS

'84 Apostolides, Prof. Nicoly Chr., Athens, Greece.
'87 Armistead, J. J., Dumfries, Scotland.
'22 Director, All-Russian Agricultural Museum, Fontanka 10, Leningrad, Russia.
'22 Director of Fisheries (British Malay), Singapore, Straits Settlements.
'08 Higginson, Eduardo, Consul for Peru, New York City.
'84 Landmark, A., Inspector of Norwegian Fresh Water Fisheries, Christiania, Norway.
'22 Library, National Museum of Natural History, Paris, France.
'84 Marston, R. B., Editor of the Fishing Gazette, London, England.
'08 Potteau, Charnley, Lommel, Belgium.
'84 Sars, Prof. G. O., Christiania, Norway.
'10 Stead, David G., Fisheries Department, Sydney, New South Wales, Australia.

PATRONS

'14 Alaska Packers Association, San Francisco, Calif.
'15 Allen, Henry F. (Agent, Crown Mills), 210 California St., San Francisco, Calif.
'15 American Biscuit Co., 815 Battery St., San Francisco, Calif.
'15 American Can Co., Mills Building, San Francisco, Calif.
'15 Armour & Co., Battery and Union Sts., San Francisco, Calif.

'15 Armsby, J. K., Company, San Francisco, Calif.
'15 Atlas Gas Engine Co., Inc., Foot of 22nd Avenue, Oakland, Calif.
'15 Balfour, Guthrie & Co., 350 California St., San Francisco, Calif.
'15 Bank of California, N. A., California and Sansome Sts., San Francisco, Calif.
'15 Bloedel-Donovan Lumber Mills, Bellingham, Wash.
'15 Bond and Goodwin, 485 California St., San Francisco, Calif.
'15 Burpee and Letson, Ltd., South Bellingham, Wash.
'15 California Barrel Co., 22d and Illinois Sts., San Francisco, Calif.
'15 California Door Co., 43 Main St., San Francisco, Calif.
'15 California Stevedore and Ballast Co., Inc., 210 California St., San Francisco, Calif.
'15 California Wire Cloth Company, San Francisco, Calif.
'15 Caswell, Geo. W., Co., Inc., 503–4 Folsom St., San Francisco, Calif.
'15 Clinch, C. G., & Co., Inc., 144 Davis St., San Francisco, Calif.
'15 Coffin-Redington Co., 35–45 Second St., San Francisco, Calif.
'15 Columbia River Packers Association, Astoria, Ore.
'15 Crane Co. (C. W. Weld, Mgr.), 301 Brannon St., San Francisco, Calif.
'15 Dodge, Sweeney & Co., 36–48 Spear St., San Francisco, Calif.
'15 First National Bank of Bellingham, Bellingham, Wash.
'15 Fuller, W. P., & Co., 301 Mission St., San Francisco, Calif.
'15 Grays Harbor Commercial Co., Foot of 3d St., San Francisco, Calif.
'15 Hendry, C. J., Co., 46 Clay St., San Francisco, Calif.
'15 Jones-Thierbach Co., The, Battery and Merchant Sts., San Francisco, Calif.
'15 Knapp, The Fred H., Co., Arcade-Maryland Casualty Building, Baltimore, Md.
'15 Linen Thread Co., The, (W. A. Barbour, Mgr.), 443 Mission St., San Francisco, Calif.
'15 Mattlage, Chas. F., Company, 335 Greenwich St., New York City.
'15 Nauman, C., & Co., 501–3 Sansome St., San Francisco, Calif.
'15 Oliver Salt Co., Mt. Eden, Calif.
'15 Morrison Mill Co., Inc., Bellingham, Wash.
'15 Morse Hardware Co., Inc., 1025 Elk St., Bellingham, Wash.
'15 Pacific Hardware and Steel Co., 7th and Townsend Sts., San Francisco, Calif.
'15 Pacific States Electric Co., 575 Mission St., San Francisco, Calif.
'15 Phillips Sheet and Tin Plate Co., Weirton, W. Va.
'15 Pope and Talbot, Foot of 3d St., San Francisco, Calif.
'15 Puget Sound Navigation Co., Seattle, Wash.
'15 Ray, W. S., Mfg. Co., Inc., 216 Market St., San Francisco, Calif.
'15 Schmidt Lithograph Co., 2d and Bryant Sts., San Francisco, Calif.
'15 Schwabacher-Frey Stationery Co., 609–11 Market St., San Francisco, Calif.
'15 Ship Owners' and Merchants' Tug Boat Co., Foot of Green St., San Francisco, Calif.
'15 Sherwin-Williams Co., The, 454 Second St., San Francisco, Calif.
'15 Smith Cannery Machine Co., 2423 South First Avenue, Seattle, Wash.
'15 Standard Gas Engine Co., Dennison and King Sts., Oakland, Calif.
'15 Standard Oil Co. of California, Standard Oil Building, San Francisco, Calif.
'15 U. S. Rubber Co. of California (W. D. Rigdon, Mgr.), 50–60 Fremont St., San Francisco, Calif.
'15 U. S. Steel Products Co., Rialto Building, San Francisco, Calif.

'15 Wells Fargo National Bank of San Francisco, Montgomery and Market Sts., San Francisco, Calif.
'15 Western Fuel Co., 430 California St., San Francisco, Calif.
'15 Western Meat Co., 6th and Townsend Sts., San Francisco, Calif.
'15 White Bros., 5th and Brannon Sts., San Francisco, Calif.

ACTIVE MEMBERS

'16 Adams, Dr. Charles C., State Museum, Univ. of the State of N. Y., Albany, N. Y.
'13 Adams, William C., Division of Fisheries and Game, State House, Boston, Mass.
'29 Ainsworth, A. L., Tuxedo Fisheries, Tuxedo Park, N. Y.
'20 Albert, W. E., State Fish and Game Warden, Des Moines, Iowa.
'98 Alexander, George L., Grayling, Mich.
'29 Allen, William Ray., Dept. of Zoology, University of Kentucky, Lexington, Ky.
'29 Allyn, Leon C., 67 Park Avenue, Rochester, N. Y.
'26 Alm, Dr. Gunnar, Commissioner of Fresh Water Fisheries, Lantbruksstyrelsen, Stockholm, Sweden.
'23 Amsler, Guy, Department of Fish and Game, Little Rock, Ark.
'08 Anderson, August J., Box 704, Marquette, Mich.
'24 Annin, Harry K., Spring Street, Caledonia, N. Y.
'14 Annin, Howard, Caledonia, N. Y.
'26 Armstrong, Hon. Harry M., Commissioner Fish and Game, 452 Montgomery St. Jersey City, N. J.
'25 Atherton, Giles, El Dorado, Kansas.
'29 Atkinson, C. J., 93 Grove St., Ottawa, Ont., Can.
'28 Avey, E. S., Elma, Wash.
'01 Babcock, John P., Provincial Fisheries Department, Victoria, B. C., Canada.
'12 Babcock, William H., 140 South Dearborn St., Chicago, Ill.
'25 Bailliere, F. Lawrence, 220 W. 19th St., Tulsa, Okla.
'27 Baker, Clarence, 2 South Carroll St., Madison, Wis.
'29 Baker, Dr. Davis, Insurance Bldg., Glens Falls, N. Y.
'15 Balch, Howard K., 158 West Austin Ave., Chicago, Ill.
'01 Baldwin, O. N., U. S. Bureau of Fisheries, San Marcos, Tex.
'98 Ball, E. M., U. S. Bureau of Fisheries, Washington, D. C.
'23 Bangham, Dr. Ralph V., Wooster College, Wooster, Ohio.
'28 Banner, James R., U. S. Bureau of Fisheries, Washington, D. C.
'20 Barbour, F. K., Linen Thread Co., 200 Hudson St., New York City, N. Y.
'05 Barbour, Prof. Thomas, Museum of Comparative Zoology, Cambridge, Mass.
'26 Barnes, J. Sanford, 52 Vanderbilt Ave., New York, N. Y.
'19–'25 Bartlett, Mott L., Concord, N. H.
'22–'29 Bayne, Bliss, Supt., Hyattville State Fish Hatchery, Hyattville, Wyo.
'28 Beakbane, Alfred Bernard, 31 Thompson Ave., Glens Falls, N. Y.
'29 Beans, Thomas A., Crawford, Neb.
'00 Beeman, Henry W., New Preston, Conn.
'28 Bell, F. Howard, International Fisheries Commission, University of Washington, Seattle, Wash.
'30 Bell, Garnet S., 18 Wellington St., W., Toronto, Can.

'18 Bellisle, J. A., Inspector General of Fisheries and Game, Quebec, Canada.
'80 Belmont, Perry, 1618 New Hampshire Ave., Washington, D. C.
'28 Bengard, F. A., Springerville, Ariz.
'25 Bengard, John P., Valley Ranch, New Mexico.
'27 Benjamin, H. F., 61 Broadway, New York, N. Y.
'28 Benjamin, S. H., P.O. Box 507, Brevard, N. C.
'29 Benson, John W., Rolette, N. D.
'13 Berg, George J., Indiana Fish Commission, Indianapolis, Ind.
'27 Berry, Frank, 2309 North 28th St., Tacoma, Wash.
'27 Biddle, Spencer, R. F. D. No. 1, Vancouver, Wash.
'27 Birdseye, Clarence, General Seafoods Corporation, Gloucester, Mass.
'28 Bishop, M. S., R. F. D. No. 2, Iroquois Trout Hatchery, Glens Falls, N. Y.
'24 Bitzer, Ralph, Montague, Mass.
'24 Blanchard, Charles, State Fish Hatchery, Unionville, Conn.
'25 Blankenship, Dr. E. L., Crystal Springs Trout Farm, Cassville, Mo.
'20 Bonner, Albert E., Coopersville, Mich.
'26 Borcea, Dr. Jean, Univ. of Jassy, Jassy, Roumania.
'25 Borger, Samuel I., Brookhaven, Long Island, N. Y.
'28 Borges, William F., 450 Broadway, Milwaukee, Wis.
'27 Boschen, W. B., 6 Lincoln Place, Freehold, N. J.
'25 Bottler, P. G., State Fish Hatchery, Emigrant, Montana.
'00 Bower, Ward T., U. S. Bureau of Fisheries, Washington, D. C.
'28 Bowlby, H. L., Appleton, Wis.
'30 Bowling, T. C., Pryor, Okla.
'30 Branion, Hugh D., Dept. of Biochemistry, University of Toronto, Toronto, Can.
'20 Breder, C. M., Jr., New York Aquarium, New York City, N. Y.
'26 Brenard, Thomas L., Care of Martin Fish Co., Atchafalaya, La.
'28 Brittain, William H., 8905 Colesville Pike, Silver Spring, Md.
'27 Brown, C. A., Hartwood, Sullivan Co., N. Y.
'16 Brown, Dell., U. S. Bureau of Fisheries, Mammoth Springs, Ark.
'26 Brown, George E., Graybar Electric Co., Inc., 413 S. 4th St., Minneapolis, Minn.
'28 Brunell, Gustav, Director del Laboratorio Centrale d'Idrobiologia, Piazza Borghese, 91, Rome, Italy.
'28 Buck, David H., Cresco, Monroe Co., Pa.
'26 Buford, Henry, State Fish Hatchery, Eastaboga, Ala.
'20 Buller, C. R., Pleasant Mount, Wayne County, Penn.
'12 Buller, G. W., Pleasant Mount, Wayne County, Penn.
'28 Bunch, W. C., Bureau of Fisheries, Edenton, N. C.
'29 Burke, Dr. Edgar, Jersey City Hospital, Jersey City, N. J.
'17 Burkhart, Joe, Big Rock Creek Trout Club, St. Croix Falls, Wis.
'07 Burnham, Charles W., U. S. Bureau of Fisheries, Louisville, Ky.
'28 Burnham, Edwin K., Bureau of Fisheries, Washington, D. C.
'28 Butler, Edward C., Box 36 B. B. Station, Boston, Mass.
'30 Butler, George Edward, Winnipegosia, Man., Canada.
'29 Butler, W. W., 621 Craig St., W., Montreal, Que., Canada.
'27 Byers, A. F., 1226 University St., Montreal, Que., Can.
'27 Cable, Louella E., Beaufort, N. C.

'30 Candee, C. N., 47 Yonge St., Toronto, Canada
'17–'22 Canfield, H. L., U. S. Fisheries Station, Homer, Minn.
'28 Carlson, Ray A., Box 275, St. Croix Falls, Wis.
'23 Catt, James, District Inspector of Hatcheries, Customs House, St. John, N. B., Canada.
'07 Catte, Eugene, Catte Fish Hatchery, Langdon, Kansas.
'28 Cayon, H. T., Deer Harbor, Wash.
'18 Chamberlain, Thomas Knight, 7 Willis Ave., Columbia, Mo.
'17 Chambers, E. T. D., Department of Colonization, Mines and Fisheries, Quebec, Canada.
'25 Christianson, William, State Fish Hatchery, St. Paul, Minn.
'29 Churchill, H. A., Sheridan, Wyo.
'29 Chute, Walter H., Director, John G. Shedd Aquarium, Grant Park, Chicago, Ill.
'29 Clapp, Alva, Secretary and State Fish and Game Warden, Pratt, Kan.
'25 Clark, George A., Topeka, Kansas.
'27 Classen, P. W., Cornell University, Ithaca, N. Y.
'21 Clemens, Dr. Wilbert A., Pacific Biological Station, Nanaimo, B. C., Canada.
'00 Cobb, Eben W., R.F.D., Farmington, Conn.
'27 Cobb, Kenneth E., R.F.D., Farmington, Conn.
'29 Cokeley, H. A., Crawford, Neb.
'04 Coker, Dr. Robert E., Univ. of North Carolina, Chapel Hill, N. C.
'26 Collins, J. L., 15 State St., Boston, Mass.
'26 Comee, Joseph F., People's Gas Bldg., Chicago, Ill.
'26 Connett, Eugene V., 3rd, 170 Turrell Ave., S. Orange, N. J.
'29 Conway, W. P., 140 Broadway, New York, N. Y.
'28 Cook, A. B., Jr., Field Supt. of Fisheries, Ionia, Mich.
'22 Cook, Frank, Laramie State Fish Hatchery, Laramie, Wyo.
'17 Cook, Ward A., U. S. Bureau of Fisheries, Duluth, Minn.
'24 Coolidge, Charles A., 122 Ames Building, Boston, Mass.
'27 Coristine, Charles G., 11 Belvedere Road, Westmount, Montreal, Que., Canada.
'24 Corson, Robert H., 2814 Boulevard, Jersey City, N. J.
'26 Cottrell, Ted, Chief Game Warden, Birmingham, Ala.
'18 Coykendall, Edward, 22 Ferry St., Kingston, N. Y.
'21 Craig, Samuel, 398 Van Norman St., Port Arthur, Ont., Canada.
'13 Crandall, A. J., Ashaway Line & Twine Mfg. Co., Ashaway, R. I.
'11 Crasser, Hugo, U. S. Bureau of Fisheries, Yellowstone Park, Wyo.
'28 Crosby, Col. W. W., Box 232, Coronado, Cal.
'30 Crowell, Mary, Shortsville, N. Y.
'25 Cuenin, J. P., San Francisco Examiner, San Francisco, Calif.
'08 Culler, C. F., U. S. Bureau of Fisheries, La Crosse, Wis.
'28 Cumings, Ed., Care Cumings Brothers, Flint, Mich.
'23 Curtis, Brian Co., 125 East 57th St., New York City, N. Y.
'12 Danglade, Ernest, Vevay, Ind.
'06 Davies, David, U. S. Fisheries Station, Put-in-Bay, Ohio.
'28 Davis, Hosea L., Fisheries Station, Mammoth Springs, Ark.
'23 Davis, Dr. H. S., U. S. Bureau of Fisheries, Washington, D. C.
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